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Ph: +91 9385339863 | www.threatenedtaxa.org
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Cover—The Summer Clicker *Lahugada dohertyi* from outskirts of Coochbehar, West Bengal © Vivek Sarkar.

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Species richness and abundance of monogonont rotifers in relation to environmental factors in the UNESCO Sakaerat Biosphere Reserve, Thailand

Nattaporn Plangklang [1], **Chaichat Boonyanusith** [2] & **Sujeephon Athibai** [3]

[1,3] Applied Taxonomic Research Center and Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.
[2] School of Biology, Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima 30000, Thailand.
[1] natt-kung@hotmail.com, [2] chaichat.b@nrru.ac.th, [3] sujiat@kku.ac.th (corresponding author)

Abstract: The UNESCO Sakaerat Biosphere Reserve plays an important role in nature conservation and environmental protection. Previous focus on terrestrial habitats and neglect of aquatic ecosystems has resulted in an incomplete picture of biodiversity of the area. Based on the first investigation of planktonic diversity, rotifers were collected seasonally at five localities from September 2013 to May 2014 using a Schindler-Patalas plankton trap and a plankton net. Fifteen families, 25 genera and 71 species of rotifers were identified. The most diverse families were Lecanidae, Brachionidae, Lepadellidae, and Trichocercidae, accounting for 80% of the total species count. The maximum species richness was reported at the reservoir, with 57 species (80% of the total), while the minimum species richness (34) was observed at the ponds. The rainy season had the highest density, followed by winter and summer, with 149.15 N/l from an intermittent stream, and 95.43 and 50.68 N/l from a pond, respectively. Most of the sampling sites at the three seasonal occasions were dominated by a planktonic species *Polyarthra vulgaris*. The results indicate that the seasonal variation of the rotifer assemblage is related to the seasonal variation of physicochemical parameters.

Keywords: Mountainous area, northeastern Thailand, seasonal variation, southeastern Asia, water quality, zooplankton.

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Author details: Mr Nattaporn Plangklang has got master's degree in Biology and is currently a PhD student at Department of Biology, Faculty of Science, Khon Kaen University. During his graduate degree program, he worked on diversity of zooplankton. Dr Chaichat Boonyanusith is a lecturer of the School of Biology, Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University. His research is focused mainly on diversity of cave-dwelling copepods, as well as surface freshwater zooplankton. Dr Sujeephon Athibai is an assistant professor at Department of Biology, Faculty of Science, Khon Kaen University. She has focused her research interests on diversity and ecology of zooplankton in freshwater ecosystem.

Author contribution: NP was responsible for data collection and analysis, laboratory work and preparation of the manuscript. CB performed multivariate analyses and preparation of the manuscript. SA designed and participated in providing funding and facilities, involved in directing and supervising field and laboratory works, analyzed the data and discussed the results and preparation of the manuscript.

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INTRODUCTION

The UNESCO Sakaerat Biosphere Reserve (SBR), the leading biodiversity hotspot in Thailand, plays an important role in nature conservation and environmental protection. It is an ideal place to conduct ecological and environmental research. Several investigations have clearly shown a high diversity of flora and fauna (e.g., fungi, mushrooms, flowering plants, insects and vertebrates), and new species continue to be discovered, including fungi (*Lauriomyces sakaeratensis*) and grasshoppers (*Arnobia tinae*) (Somrithipol et al. 2006; Tan & Artchawakom 2014). Interest in the diversity of aquatic fauna has been limited to date, however; until recently, only two studies have been reported. The first involved the investigation of harpacticoid copepods (Boonyanusith & Athibai 2014), while the more recent one focused on the discovery of the rare freshwater sponge of Australasia at an intermittent stream (Ruengsawang et al. 2017).

Monogonont rotifers, in general, are the most diverse metazoan zooplankton. On a global scale, they comprise about 1,583 species belonging to 112 genera and 30 families (Segers 2011). In continental water bodies, they are predominant in the littoral zone of both permanent and temporary waters, acting as primary consumers in the trophic stage. Additionally, they are used as bioindicators to study the influence of environmental factors in water bodies (Negreiros et al. 2010). The diversity and distribution of rotifers in Thailand has been investigated primarily in surface water-bodies in lowland areas. Since the first publication for the country (Ueno 1966), the number of known Thai rotifers has increased remarkably. Previous comprehensive studies have provided valuable knowledge of the distribution of rotifers in Thailand (e.g., Sanoamuang et al. 1995; Sanoamuang & Savatenalinton 1999; Chittapun et al. 2007; Segers & Savatenalinton 2010; Athibai et al. 2013; Meksuwan et al. 2013), and 399 taxa of monogonont rotifer have been recorded (Sa-ardrit et al. 2013; Meksuwan et al. 2018). Nevertheless, considering the diversity of zooplankton in SBR it is necessary to fill the gaps in our knowledge. In this contribution, the species list and abundance of monogonont rotifers are provided based on sampling done in three seasons (rainy, winter and summer) at five sampling sites with various aquatic habitats within the Sakaerat Environmental Research Station (SERS), the core portion of the UNESCO SBR.

MATERIALS AND METHODS

Study area

Sakaerat Biosphere Reserve, the first of four UNESCO biosphere reserves in Thailand, is situated in the Sankamphaeng mountain range on the southwestern margin of the Khorat Plateau, Nakhon Ratchasima Province, in northeastern Thailand. Located between 14.445–14.542 ^{0}N and 101.844–101.955 ^{0}E, it covers approximately 82,100ha at an elevation of 250–762 m. The average annual temperature in that region is 26^{0}C, and the average annual rainfall is 1,260mm (Ruengsawang et al. 2017). Sakaerat Environmental Research Station is the core portion of the SBR. It was established to promote long-term ecological research, and to demonstrate sustainable forest management and biodiversity conservation (Trisurat 2010). Within the SERS and its buffer zone, nine habitats have been classified, comprising dry evergreen forest, mixed deciduous forest, dry dipterocarp forest, grassland, secondary growth vegetative forest, plantation, agriculture and settlement, old clearing, and water body (Trisurat 2010). In this study, monogonont rotifers were investigated at five sampling sites (Fig. 1). The location, altitude and habitat type of each are in Table 1.

Rotifer sampling and identification and environmental factors measurement

Qualitative and quantitative samples were collected seasonally in the rainy, summer and winter seasons between September 2013 and May 2014 from the five sampling localities, using a Schindler-Patalas plankton trap and a plankton net (60µm mesh size). The rotifers were then immediately preserved with 4% formaldehyde solution. Nine physicochemical parameters were measured: water temperature, transparency, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), orthophosphate content (PO_4^{3-}), nitrate content (NO_3^-) and total ammonia content (NH_3). The rotifer specimens were subsequently sorted, counted and identified under an Olympus-CH30 compound light microscope. The rotifers were identified to species level, according to Koste & Shiel (1992), Nogrady et al. (1995), Segers (1995), De Smet & Pourriot (1997), and Nogrady & Segers (2002).

Data analysis

The similarity of the faunal assemblages among the sampling sites and the seasons was evaluated by clustering. The operation was based on the Bray-Curtis dissimilarity coefficient. A canonical correspondence

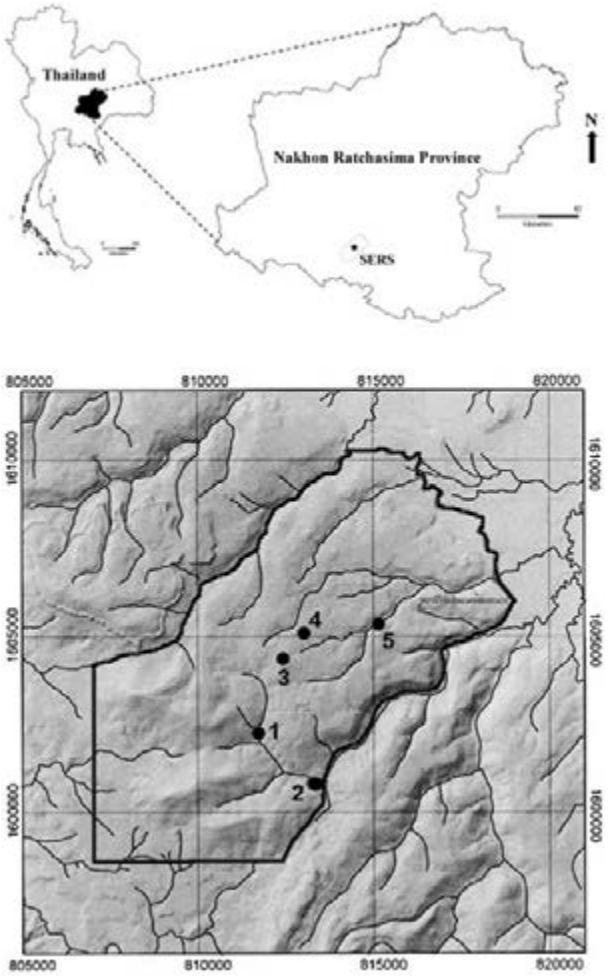

Figure 1. Sakaerat Environmental Research Station in Thailand showing sampling sites.

Table 1. Geographic coordinates of the sampling sites within the Sakaerat Environmental Research Station.

Sampling site code	Latitude ^{0}N	Longitude ^{0}E	Altitude (m)	Habitat type
S1	14.476	101.888	370	Stream
S2	14.466	101.903	392	Reservoir
S3	14.499	101.900	608	Pond
S4	14.501	101.902	560	Pond
S5	14.506	101.919	422	Stream

analysis (CCA) was later performed to examine the relationships between the environmental factors and the rotifer species.

In the data matrix of species abundance, taxa that occurred more frequently than 1% of all samples were included in the analysis (Yang et al. 2005). The data of abundance and environmental parameters were transformed by log10 (x + 1) before analysis. Data analysis was conducted by PC-ORD, version 5.0 (McCune & Mefford 2006).

The differences in nine environmental factors and the density of rotifers during three seasons at five sampling localities were analyzed using one-way ANOVA and IBM SPSS Statistics for Windows, version 19 (IBM Corp., Armonk, NY, USA). Furthermore, comparisons of the means were conducted using Duncan's multiple range test ($p < 0.05$).

RESULTS

Rotifer richness

Rotifer fauna collected on three seasonal occasions from five water-bodies within the SERS were investigated. A total of 71 species, belonging to 23 genera and 15 families of monogonont rotifers, were found (Table 2); illustrations of selected species are shown at Image 1. The most diverse family was Lecanidae (26 species, 36.62%) and Brachionidae (13 species, 18.31%). The next two most-diverse families were Trichocercidae and Lepadellidae, accounting for eight and six species, respectively. The greatest number of rotifer species (56) was reported during the rainy season. Based on the number of species per habitat (α-diversity), the α-diversity recorded from the rainy season was similar to that of the summer season. During the rainy season, the richness of the rotifers varied from nine to 44 species, compared to nine to 43 species found in summer, but the α-diversity was lower in winter (seven to 31 species). When comparing the habitat types, the reservoir had the highest diversity (57 species), followed by the stream (35 species) and the pond (34 species). The most frequently encountered species were *Polyarthra vulgaris* (80% of samples), *Keratella tropica* (73%), and *Lecane bulla* (73%). *Ascomorpha ovalis*, *Brachionus forficula*, *Cephalodella gibba*, *Lecane haliclysta*, *L. obtusa* and *Trichocerca scipio* were recorded during the rainy season only. *Lecane pyriformis*, *L. stenroosi*, *Lepadella quadricarinata* and *Trichocerca cylindrica* were observed only in winter; in contrast, *Brachionus calyciflorus*, *Dipleuchlanis propatula*, *Euchlanis dilatata*, *Lecane aculeata*, *L. latissima*, *Lecane superaculeata* and *L. tenuiseta* were present only in summer. Moreover, *Brachionus calyciflorus*, *Lecane haliclysta*, *L. stenroosi,* and *L. quadricarinata* were recorded only at the stream. *Brachionus forficula*, *Cephalodella gibba, Dipleuchlanis propatula*, *Euchlanis dilatata*, *Lecane aculeata*, *L. latissima*, *L. obtusa*, *L. pyriformis*, *L. superaculeata,* and *Trichocerca scipio* were found only at the reservoir.

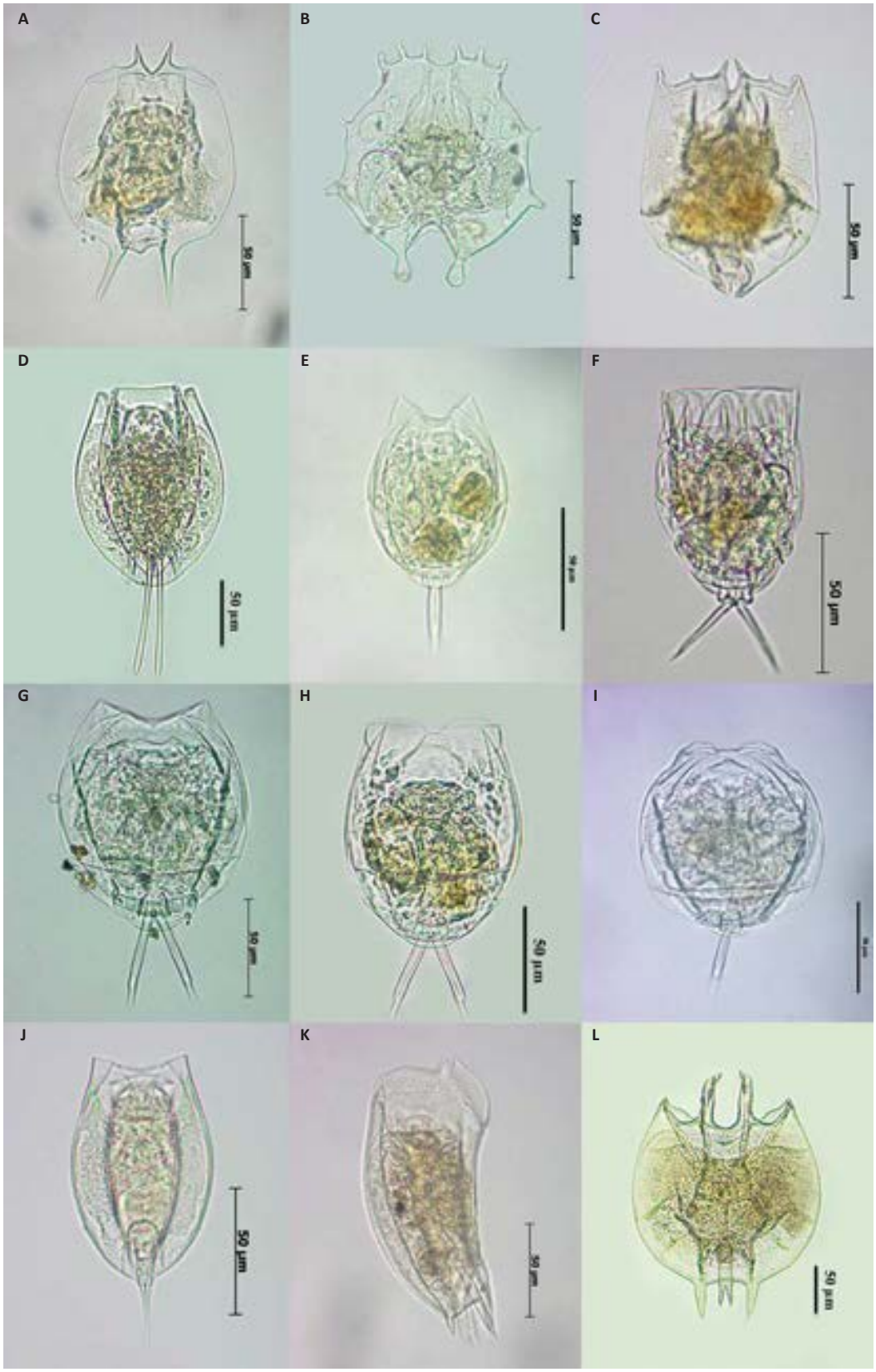

Image 1. Species of Rotifera: A—*Brachionus dichotomus reductus* Koste & Shiel, 1980 | B—*Brachionus donneri* Brehm, 1951 | C—*Brachionus kostei* Shiel, 1983 | D—*Dipleuchlanis propatula* (Gosse, 1886) | E—*Lecane hamata* (Stokes, 1896) | F—*Lecane haliclysta* Harring & Myers, 1926 | G—*Lecane lateralis* Sharma, 1978 | H—*Lecane papuana* (Murray, 1913) | I—*Lecane unguitata* (Fadeev, 1926) | J—*Lepadella rhomboides* (Gosse, 1886) | K—*Mytilina ventralis* (Ehrenberg, 1830) | L—*Platyias quadricornis* (Ehrenberg, 1832). © Nattaporn Plangklang.

Table 2. Recorded rotifers found at five inland waters with different habitat types, by season, at the Sakaerat Environmental Research Station. 1—rainy season, 2—winter season, 3—summer season; species occurrence is characterized by present (+), absent (–).

	Sampling sites														
	S1			S2			S3			S4			S5		
Scientific name	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Family Asplanchnidae															
Asplanchna sieboldii (Leydig, 1854)	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–
Family Brachionidae															
Anuraeopsis fissa Gosse, 1851	–	–	+	–	–	+	+	–	+	+	–	+	+	–	+
Brachionus calyciflorus Pallas, 1766	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Brachionus dichotomus reductus Koste & Shiel, 1980	–	–	–	+	–	+	–	–	–	+	–	–	–	–	–
Brachionus donneri Brehm, 1951	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–
Brachionus falcatus Zacharias, 1898	+	–	–	+	+	+	–	–	–	+	–	+	–	–	+
Brachionus forficula Wierzejski, 1891	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Brachionus kostei Shiel, 1983	+	–	–	–	–	–	+	+	+	–	–	–	–	–	–
Brachionus quadridentatus Hermann, 1783	+	+	+	+	+	–	–	+	–	–	+	+	–	–	–
Brachionus quadridentatus mirabilis Daday, 1897	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Keratella cochlearis (Gosse, 1851)	–	–	–	+	+	+	–	–	+	–	–	–	+	–	–
Keratella tropica (Apstein, 1907)	+	+	+	+	+	+	–	+	+	+	+	+	–	–	–
Plationus patulus (Müller, 1786)	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Platyias quadricornis (Ehrenberg, 1832)	+	–	+	+	–	+	–	–	–	+	+	–	–	–	–
Family Euchlanidae															
Dipleuchlanis propatula (Gosse, 1886)	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Euchlanis dilatata Ehrenberg, 1832	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Euchlanis incisa Carlin, 1939	+	+	–	+	+	+	–	–	–	–	–	–	+	–	–
Family Gastropodidae															
Ascomorpha ovalis (Bergendal, 1892)	–	–	–	+	–	–	–	–	–	+	–	–	–	–	–
Family Hexarthridae															
Hexarthra intermedia (Wiszniewski, 1929)	–	–	–	+	–	+	+	–	–	–	–	–	–	–	–
Family Lecanidae															
Lecane aculeata (Jakubski, 1912)	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Lecane bulla (Gosse, 1851)	+	+	+	+	+	+	–	+	–	+	–	+	–	+	+
Lecane closterocerca (Schmarda, 1859)	+	+	–	+	+	–	–	+	–	+	–	–	+	+	–
Lecane curvicornis (Murray, 1913)	+	–	+	+	+	+	–	–	–	–	+	–	–	+	–
Lecane flexilis (Gosse, 1886)	–	+	–	–	–	–	–	–	–	+	+	–	–	–	–
Lecane furcata (Murray, 1913)	–	–	–	–	+	–	–	–	–	–	–	–	+	–	+
Lecane haliclysta Harring & Myers, 1926	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane hamata (Stokes, 1896)	+	–	+	+	+	+	–	–	+	–	–	–	+	+	+
Lecane hornemanni (Ehrenberg, 1834)	–	+	–	–	–	+	–	–	+	–	–	+	–	–	–
Lecane lateralis Sharma, 1978	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–
Lecane latissima Yamamoto, 1955	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Lecane leontina (Turner, 1892)	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–
Lecane ludwigii (Eckstein, 1883)	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane luna (Müller, 1776)	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–
Lecane lunaris (Ehrenberg, 1832)	+	+	–	+	+	+	–	–	–	–	+	+	–	–	+
Lecane nitida (Murray, 1913)	–	–	–	+	–	+	–	–	+	–	–	–	–	–	–
Lecane obtusa (Murray, 1913)	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Lecane papuana (Murray, 1913)	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–
Lecane pyriformis (Daday, 1905)	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–

	Sampling sites														
	S1			S2			S3			S4			S5		
Scientific name	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Lecane quadridentata (Ehrenberg, 1830)	+	+	–	+	+	+	–	–	–	–	–	–	–	–	–
Lecane signifera (Jennings, 1896)	–	–	–	+	+	+	–	+	–	–	–	+	–	–	–
Lecane stenroosi (Meissner, 1908)	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Lecane superaculeata Sanoamuang & Segers, 1997	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Lecane tenuiseta Harring, 1914	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–
Lecane unguitata (Fadeev, 1926)	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–
Lecane ungulata (Gosse, 1887)	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–
Family Lepadellidae															
Colurella uncinata (Müller, 1773)	–	–	–	–	–	–	–	+	–	–	–	–	+	+	+
Lepadella acuminata (Ehrenberg, 1834)	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–
Lepadella dactyliseta (Stenroos, 1898)	+	+	–	+	+	+	–	–	–	–	–	–	–	–	–
Lepadella patella (Müller, 1773)	+	+	–	+	–	+	–	+	+	–	+	+	–	–	+
Lepadella quadricarinata (Stenroos, 1898)	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Lepadella rhomboides (Gosse, 1886)	+	–	–	–	–	–	–	+	+	–	–	–	+	+	+
Family Mytilinidae															
Mytilina acanthophora Hauer, 1938	+	+	–	–	–	–	+	+	+	–	+	–	–	–	+
Mytilina ventralis (Ehrenberg, 1830)	+	–	–	–	+	+	+	–	–	–	+	–	–	–	–
Family Notommatidae															
Cephalodella forficula (Ehrenberg, 1830)	–	–	–	+	–	+	–	–	–	–	–	–	–	–	+
Cephalodella gibba (Ehrenberg, 1830)	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Monommata longiseta (Müller, 1786)	–	–	–	+	+	+	–	–	–	–	–	–	–	+	–
Family Scaridiidae															
Scaridium longicaudum (Müller, 1786)	–	–	–	+	–	+	–	–	–	–	+	–	–	–	–
Family Synchaetidae															
Polyarthra vulgaris Carlin, 1943	+	+	+	+	+	+	+	+	+	–	–	+	+	–	+
Family Testudinellidae															
Testudinella patina (Hermann, 1783)	+	–	–	+	+	+	–	–	–	–	+	+	–	–	–
Family Trichocercidae															
Trichocerca bicristata (Gosse, 1887)	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–
Trichocerca bidens (Lucks, 1912)	–	–	–	+	+	–	–	+	–	–	+	+	–	–	–
Trichocerca capucina (Wierzejski & Zacharias, 1893)	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–
Trichocerca cylindrica (Imhof, 1891)	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Trichocerca insulana (Hauer, 1937)	–	+	–	+	+	–	–	–	–	–	–	–	–	–	–
Trichocerca pusilla (Jennings, 1903)	–	–	–	–	–	–	+	–	+	+	–	+	–	–	–
Trichocerca scipio (Gosse, 1886)	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Trichocerca similis (Wierzejski, 1893)	–	–	–	+	+	+	+	+	+	+	+	+	–	–	–
Family Trichotriidae															
Macrochaetus sericus (Thorpe, 1893)	–	–	–	+	–	+	–	–	–	–	–	–	–	–	–
Trichotria tetractis (Ehrenberg, 1830)	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–
Family Trochosphaeridae															
Filinia longiseta (Ehrenberg, 1834)	–	–	–	+	+	+	+	–	–	+	–	+	+	–	–
Filinia opoliensis (Zacharias, 1898)	–	–	–	+	+	+	–	–	–	–	–	–	–	–	–
Total number of species during each season	23	17	9	44	31	43	9	14	14	13	14	15	10	7	13
Species richness at each sampling site	29			57			24			25			19		

Finally, *Lecane tenuiseta* and *Trichocerca cylindrica* were observed only at the pond.

Rotifer density

The density of the rotifers varied by season and sampling site. The densities at S1 (stream; $F_{2, 8}$ = 23.689, p = 0.001), S2 (reservoir; $F_{2, 8}$ = 11.396, p = 0.009) and S5 (intermittent stream; $F_{2, 8}$ = 42.925, p < 0.001) are seasonally significant differences; by comparison, those of S3 (pond) and S4 (pond) were not significantly different. The greatest number of rotifers at S1, S2, and S5 was 13.91N/l in the rainy season, 29.43N/l in summer, and 149.15N/l in the rainy season, respectively. The sampling site with the highest abundance in the rainy season was S5 (the intermittent stream; 149.15N/l), whereas the greatest number during winter (95.43N/l) and summer (50.68N/l) was at S3 (pond). *Filinia longiseta* was most prominent at S5 in the rainy season, with a density of 96.63 ± 28.57 N/l (64.79%); while S3 was dominated by *Brachionus quadridentatus* in winter and *Polyarthra vulgaris* in summer, with densities of 84.78 ± 51.57 N/l (88.84%) and 28.03 ± 19.73 N/l (55.31%), respectively. In contrast, the lowest densities in the rainy, winter and summer seasons were observed at S2 (6.25N/l), S5 (0.38N/l) and S1 (1.22N/l), respectively. In addition, of the 15 families encountered, Brachionidae, Lecanidae, Trichocercidae, and Synchaetidae were the most dominant. The first three families are most prominent at all of the sampling sites in the rainy season. The intermittent stream S5 had a remarkably different rotifer assemblage to the other sites in the rainy season as the density of Trochosphaeridae was over 60%. During winter, when the highest density of Brachionidae, Synchaetidae, and Trichocercidae occurred, the sampling sites generally showed a low density of rotifers (< 10N/l) except S3, whose density (95.43N/l) was noticeably higher, with Brachionidae accounting for 84.78% of the specimens at the S3 site. Among the 15 families, the Brachionidae was the most frequently observed, being present at over 50% of the study sites. In summer, the densities of rotifers obviously increased from those during winter. Most of the sampling localities were dominated by Brachionidae, Lecanidae, Synchaetidae, and Trichocercidae (Fig. 2). The most prominent species during each season varied slightly. Three species, namely, *Lecane bulla*, *Polyarthra vulgaris,* and *Trichocerca similis* were predominant and common at several sampling sites in all seasons.

Environmental parameters

The physicochemical parameters of water data were obtained during three seasons (rainy, winter and summer) from five sampling sites (S1, S2, S3, S4, and S5); the grouping was categorized into three different habitat types (pond, reservoir, and stream). The statistical analysis showed that five parameters (water temperature, pH, transparency, NH_3, and EC) at each sampling site displayed significant differences among the seasons (p < 0.05). The value of water temperature had the highest in summer and lowest in winter. The pH of water in the rainy season was slightly acidic to neutral (6.51–7.44), whereas that in winter and summer was

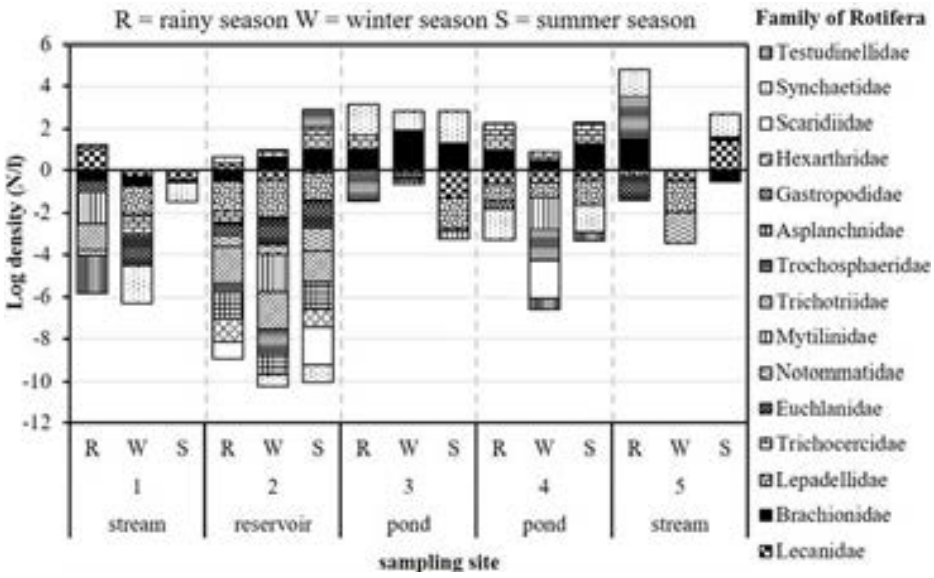

Figure 2. Log density of rotifer families at five sampling sites during different seasons.

slightly acidic (5.17–6.70) and acidic to slightly acidic (4.54–6.32), respectively. The pH was lowest at S5, with a mean of 4.54 ± 0.36. The NH_3 value at S3 was the highest in all seasons, with 2.04 ± 0.12 mg/l in the rainy season, 0.93 ± 0.09 mg/l in winter and 1.92 ± 0.04 mg/l in summer. In addition, the NH_3 value at S1 (the stream) was high in the summer (1.81 ± 0.22 mg/l).

The Pearson correlation from the CCA analysis showed that EC and TDS had a strongly positive correlation with NH_3. The correlation coefficients between EC and TDS, EC and NH_3, and TDS and NH_3 were 0.996, 0.937 and 0.953, respectively. In contrast, EC, TDS, and NH_3 were negatively correlated with DO; the coefficients between EC and DO, TDS and DO, and NH_3 and DO, were 0.568, 0.608 and 0.615, respectively. The ranges of EC, TDS, NH_3 and DO during those two seasons were, respectively, 153–161 µS/cm, 74–81 mg/l, 1.92–2.16 mg/l and 1.0–1.7 mg/l in the rainy season, and 125–133 µS/cm, 65–70 mg/l, 1.88–1.96 mg/l and 1.6–2.4 mg/l during the summer.

Seasonal variation of rotifer community

A cluster dendrogram was constructed; it was based on the data of 12 species at each sampling locality in the three seasons. The results revealed three major groupings (Fig. 3). Sampling sites S1 and S5 were clustered together, which corresponded to the winter community. Both sites were streams and had a low density of rotifers; *Lecane bulla* was predominant at both sites. Cluster 2 comprised the majority of the sampling sites and could be separated into two sub-clusters. Cluster 2A was composed mainly of two lentic habitats (S3 in all seasons, and S4 during the rainy season and summer) and one lotic water (S5 in the rainy season). This subgroup had a high density of six dominant species: *Anuraeopsis fissa*, *Brachionus kostei*, *B. quadridentatus*, *Filinia longiseta, Polyarthra vulgaris,* and *Trichocerca pusilla*. Cluster 2B included two water bodies: S2 (the reservoir) in the winter and the summer, and S4 (one of the ponds) in winter. This sub-cluster was made up of three predominant species: *Filinia opoliensis*, *Keratella tropica,* and *Trichocerca similis*. Cluster 3 consisted of three sampling sites, S1 (the stream) in the rainy season and summer, S2 in the rainy season, and S5 in summer. This cluster was grouped by the occurrence of three species (*Lecane bulla*, *L. curvicornis,* and *Mytilina acanthophora*). Focusing on S1 and S2 in the rainy season, both water bodies showed a strong relationship between them because they were situated in the same watershed, resulting in the similarity of their species occurrences and the equality of their densities.

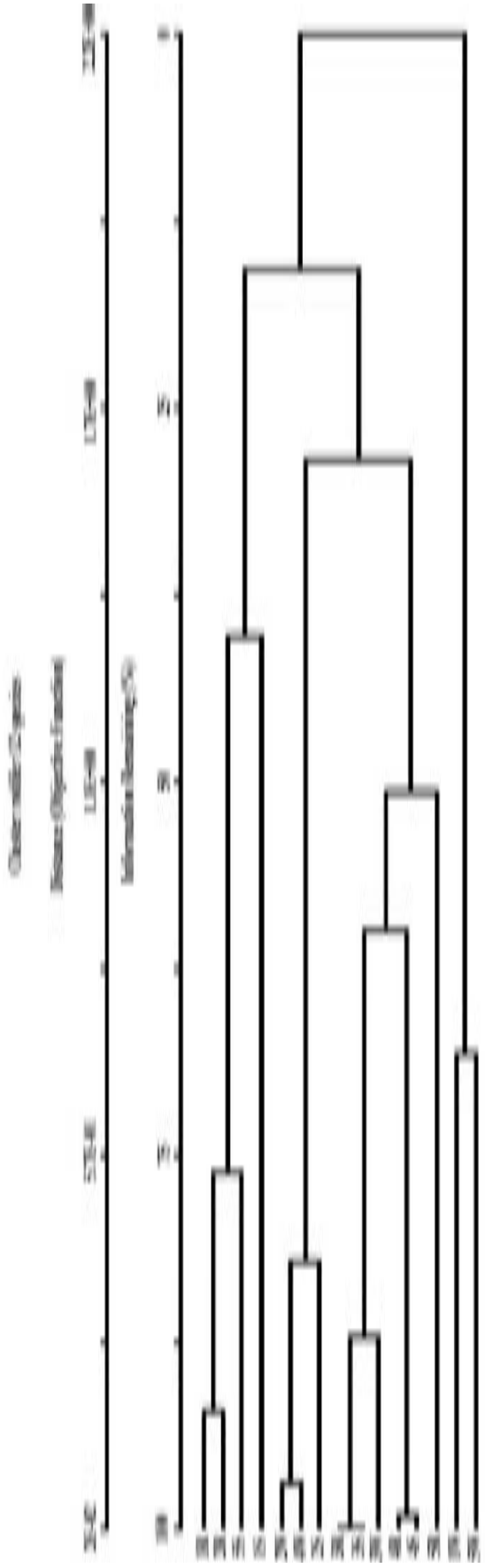

Figure 3. Hierarchical cluster analysis of sampling sites (sites 1, 2, 3, 4 and 5) during different seasons (R: rainy season, W: winter season, S: summer season), using Bray-Curtis similarity distances.

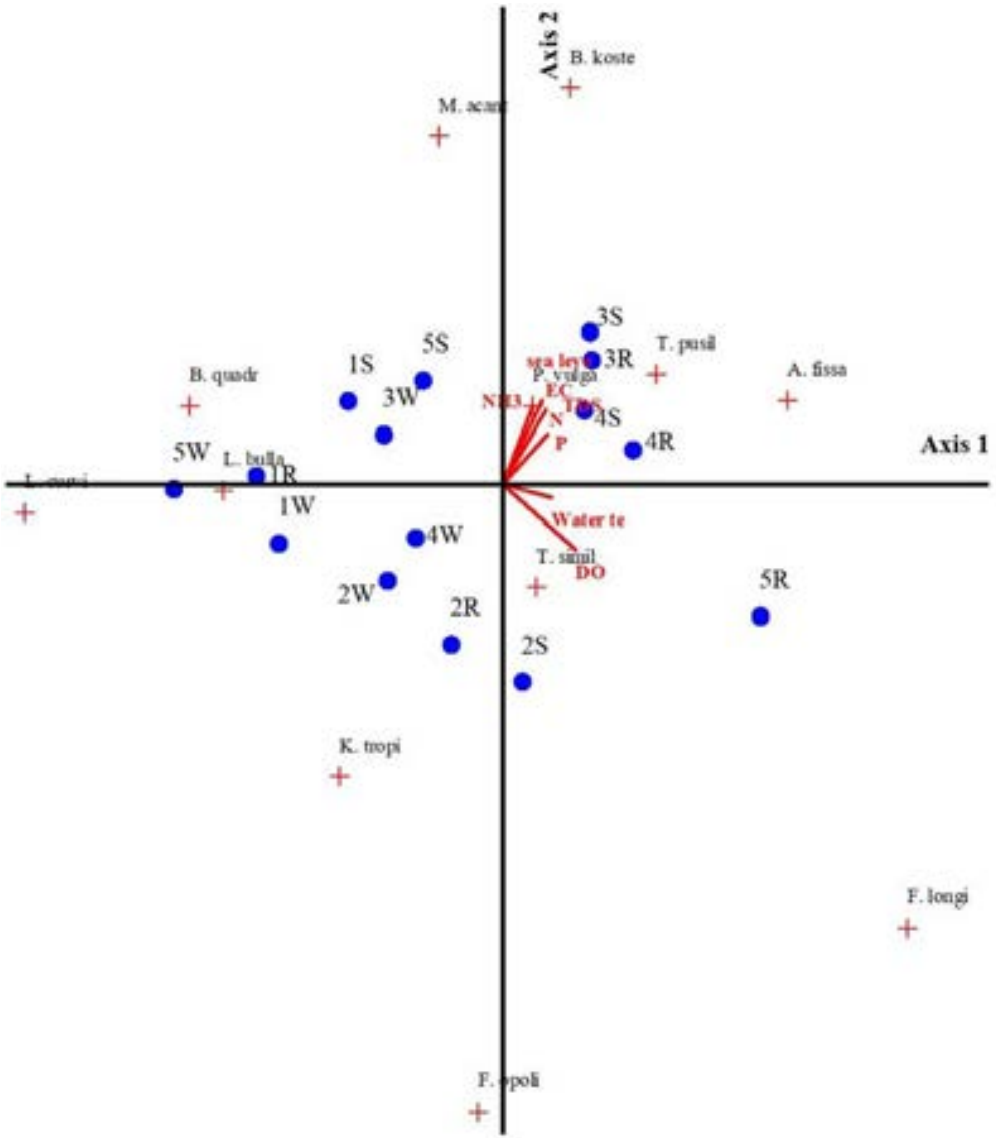

Figure 4. Canonical correspondence analysis (CCA) triplot of rotifer species and physicochemical parameters of water in inland waters of the Sakaerat Environmental Research Station. The physicochemical parameters of water; Water te: water temperature (°C), Transpar: transparency (cm), DO: dissolved oxygen (mgL^{-1}), EC: electrical conductivity (µScm^{-1}), TDS: total dissolved solid (mgL^{-1}), P: orthophosphate (mgL^{-1}), N: nitrate (mgL^{-1}) and NH_3: ammonia (mgL^{-1}). The numbers 1, 2, 3, 4, 5 indicate the sampling site numbers, and the letters R, W and S refer to the rainy, winter and summer seasons, respectively.

Relationships between rotifer community structure and environmental factors

Out of the 71 rotifer species, 12 that had a relative density of more than 1% were used for a CCA analysis. The percentages of the explained variance on the first and the second axes is 22.1 and 16.7, respectively. The species that are positively correlated to EC, TDS, NH_3, NO_3^-, PO_4^{3-}, and altitude are *Anuraeopsis fissa*, *Brachionus kostei*, *Polyarthra vulgaris* and *Trichocerca pusilla* (Fig. 4). The density of those species was high in the two ponds (S3 and S4 in the rainy and summer). A high density of *Brachionus kostei* was found at S3 in the summer season, with 19.57 N/l. Additionally, *Filinia longiseta*, *F. opoliensis,* and *Trichocerca similis* are positively correlated to water temperature and DO. High densities of the three species were present at the intermittent stream (S5) in the rainy season and at the reservoir (S2) in summer, when there were relatively high temperatures and DO levels. In particular, *Filinia longiseta* had the maximum density, with 96.63 N/l at S5 in the rainy season. In contrast, *Keratella tropica* showed a negative correlation with the major factors, including

EC, TDS, NH_3, NO_3^-, PO_4^{3-}, and altitude. *Keratella tropica* predominated at the sites that had low values for those factors, such as the pool region of the S1 stream (in winter), the S4 pond (in winter) and the reservoir (S2, in the rainy season and winter). Four species, *Brachionus quadridentatus*, *Lecane bulla*, *L. curvicornis,* and *Mytilina acanthophora* were negatively correlated with water temperature and DO. They had high densities at the sites that had low values for temperature and DO, the stream S1 (in all seasons), the S3 pond (in winter) and the pool of the intermittent stream (S5, in winter and summer). However, the Monte Carlo permutation test showed that the axis does not have any statistical significance with any of the physicochemical parameters of the water.

DISCUSSION

Rotifer richness

The 71 species of rotifer within the SERS represent 37.37% of the 190 species known at 77 localities within Nakhon Ratchasima Province (Savatenalinton 1999) and circa 17.79% of the 399 monogonont rotifers recorded in Thailand. The diversity of rotifer within the SERS is relatively low, compared with the total number of species of freshwater rotifers recorded in Thailand (Sa-ardrit et al. 2013; Meksuwan et al. 2018). This is probably due to the differences in the number of samples and habitat characteristics. In general, the diversity of plankton is quite high in lowland areas due to a large number of relatively large, stagnant waterbodies (Obertegger et al. 2010). In general, monogonont rotifers are especially diverse in the littoral zones of stagnant waters which have soft, slightly acidic and under oligo- to mesotrophic conditions (Segers 2008). This contrasts with the situation in mountainous areas, where running water, such as streams, is common. Flowing water has been identified as a limiting factor that results in reduced species diversity of rotifers (Sulehria & Malik 2012). However, rotifer species richness at SERS is numerically higher than those found at other conservation and mountain areas, such as Nam Nao National Park, Phetchabun Province, where 11 species of monogonont rotifers were encountered, and Phu Hin Rong Kla National Park, Phitsanulok Province, where 12 species were found in waterfall mosses (Savatenalinton & Segers 2008; Athibai 2014). Only a few species have commonly been encountered at those two parks. Only one cosmopolitan species, *Keratella tropica*, was recorded in the two aforementioned studies as well as the current study. This species was considered as tolerant species because they can live in highly polluted waters (Kulshrestha et al. 1991; Javed 2006) and eutrophic waters (Guevara et al. 2009). This incidence indicates that *Keratella tropica* has a wide range of ecology. In addition, Lecanidae was highly diverse at many sampling sites in the current study, which concurs with previous studies done in northeastern and southern Thailand (e.g., Sanoamuang et al. 1995; Chittapun et al. 2007). Genus *Lecane* has a high diversity in tropical regions and has frequently been found in neighboring countries such as Laos PDR (Segers & Sanoamuang 2007), Cambodia (Sor et al. 2015), and Vietnam (Dang et al. 2013). Several species in our study were widely distributed and found in almost every type of water body such as *Lecane bulla*, *L. closterocerca*, *L. curvicornis*, *L. hamata*, *L. lunaris,* and *L. papuana*. Compared with species richness of monogonont rotifers in Nokrek Biosphere Reserve, India, a number of rotifers in the latter (67 species) were close to the observed species richness in the present study; particularly, rotifer species exhibited 60.8% similarity with 42 shared species between this work and Nokrek Biosphere Reserve (Sharma & Sharma 2011). The species composition of the rotifers at the three different habitat types within the SERS, however, was different. The reservoir had the most diverse habitat, followed by the stream and then the pond. This indicated that the distribution of a certain species depends on the habitat type (Gürbüzer et al. 2017) and whether a habitat shows a high diversity of microhabitats (Arora & Mehra 2003). In case of SERS, the reservoir and streams were densely covered by macrophytes in the littoral region, providing various microhabitats. This has been found to affect the distribution and composition of rotifers (Duggan et al. 1998**).** Similarly, Ali et al. (2007) reported that subtropical freshwater invertebrates had the highest species diversity in various types of macrophytes. Furthermore, the species preferences of rotifers have been shown to differ depending on the macrophyte species (Choi et al. 2014**)**. Given that it is a common species, *Polyarthra vulgaris* was expected to be common and dominant in the inland waters of the SERS. Similarly, this species has been found to be common in certain habitats, such as the Cambodian Mekong River Basin (Meas & Sanoamuang 2008) and the eight lakes in the central Anatolia, Marmara, and western Black Sea regions of Turkey (Ergönül et al. 2016).

Rotifer density

A seasonal variation in rotifer density was evident at all of the sampling sites in the SERS; the densities of the rotifers at S1, S2, and S5 differed significantly between the seasons ($p < 0.05$). At site S5, the density of rotifers was

greatest in the rainy season. The physical characteristic of the S5 sampling area was rock pool, and the slow-flowing water was densely covered by free-floating macrophytes (*Lemna perpusilla*) during the rainy season. The macrophytes at that site disappeared in winter but regenerated in summer; during both those seasons, the water level was lower than in the rainy season. Nitrate and orthophosphate contents seem to be influencing factors for rotifer composition in SERS. As to the S5 site, both parameters were high in the rainy season, with 1.93 ± 0.46 and 0.45 ± 0.39 mg/l, respectively. Generally, nitrates and phosphates are common nutrients in aquatic habitats; they promote phytoplankton growth, and their concentrations in the water column can significantly increase or decrease the phytoplankton biomass (Pelczar et al. 2010). Meanwhile, zooplankton growth is impacted by the phytoplanktonic density because the zooplanktons graze upon the phytoplankton (Thompson et al. 1982). Therefore, seasonal variation also influences the plankton communities. Moreover, this site seems to be a eutrophic habitat because the nitrate and orthophosphate content in this study exceeded 1,500µg/l of total nitrogen and 75µg/l of total phosphorus (Dodds & Smith 2016). Those characteristics of the sampling site would affect the rotifer density (Rothhaupt 1995). The greatest density of rotifers was recorded in the rainy season, accounting for 99% of the total density. Three rotifer species were dominant in that period: *Filinia longiseta* (64.78%), *Anuraeopsis fissa* (20.81%) and *Polyarthra vulgaris* (13.23%). Those three species have also been found in eutrophic habitats (Saunders-Davies 1989; Basińska & Kuczynska-Kippen 2009). According to S3 (one of the two ponds), it was observed to have the highest density of rotifers in winter and summer. *Brachionus quadridentatus* was the dominant species in the winter, with an 88.84% relative density, but that species disappeared in the summer. Both *Polyarthra vulgaris* and *Brachionus kostei* were found to be predominant in summer, with relative abundances of 55.31% and 38.61%, respectively. Rotifers in the genus *Brachionus* and *Polyarthra* are euplanktonic rotifers, and several species of the genera are present in the littoral region of water bodies (Virro 1993). From our observations during the sampling, macrophytes were present at only three localities; therefore, the dominant species were probably both the planktonic and epiphytic rotifers. For example; macrophytes (*Hydrilla verticillata*) were present at S1 in the rainy season, and *Lecane* and *Lepadella* were found to be the dominant genera at that site.

Environmental parameters

Seasonal variations in the physicochemical parameters at the five sampling sites in the SERS were reported; five parameters, water temperature, pH, transparency, ammonia, and EC, had seasonally significant differences ($p < 0.05$). Ranging from 19.0–32.9°C, the water temperature was the lowest and the highest in winter and summer, respectively. Generally, water temperature is mainly influenced by factors such as air temperature, solar radiation, wind speed, cloud cover, humidity, precipitation, evaporation, and topography (Li et al. 2017), however, the sampling time should also be considered because it could result in differences in temperature readings throughout the day (Orr et al. 2015). As to pH, the mean pH values of the five sampling sites ranged from highly acidic to circumneutral (4.54–7.44). During summer (May), water in the intermittent stream (S5) recorded the lowest value (4.54 ± 0.36). The physical characteristic of this sampling site was a rock pool with brown water. The evidence is similar to that of a previous study by Tevapawat & Sangpradub (2017), who found that the water at S5 in the summer was brown in color and that its pH (5.59 ± 0.26) was slightly higher than observed in the present study. We assumed that the brown color and high acidity of the water resulted from organic decomposition (Winterbourn & Collier 1987). Moving on to NH_3, high values of NH_3 were reported in pond (S3) in all seasons, but particularly during the rainy season, when it peaked at 2.04 ± 0.12 mg/l. In general, ammonia is considered the first nitrogenous form to occur in freshwater habitats after its release into natural waterways through sewage discharges, the excretion of nitrogenous wastes from animals, and organic matter decomposition (Thurston & Russo 1983). In the present study, the S3 site was a small pond providing water for wildlife, and much leaf litter fell into the site during each of the three seasons. It, therefore, seems probable that the high NH_3 value of this site results from the excretion of nitrogenous wastes from wildlife, leaf litter decomposition, and nutrient loading during the rainy season. In addition to the litter decay in the S3 pond, dissolved oxygen (DO) would seem to be a limiting factor in the environment since oxygen is not only a source of aquatic animal respiration but also an input to the decomposition process. This study revealed that the DO values at S3 were low during all three seasons, with their mean ranging between 1.30 and 2.03 mg/l. The trend of the DO and nitrogen values is similar to the findings of the study by Stoler & Relyea (2016), which reported that DO showed a negative correlation with the leaf litter decay rate and the ratio of

carbon to nitrogen (C:N) in the pond at the Pennsylvania State in USA.

Relationship between habitats, environmental factors and rotifer abundance

The clustering showed that two factors affect the distribution and diversity of the rotifers in the SERS. The first is the connectivity between them (Schöll 2009), and the second is the habitat type (Sor et al. 2015). In terms of the location of the five sampling sites, S3 and S4 are the closest. Given that both sites are man-made water bodies constructed as water sources for the local wildlife which can connect and distribute through both regions. The resting eggs of rotifers may attach to the feet, fur and feathers of other wildlife. So, the dispersion of rotifers between the two sites is probably generated by animals (Zhdanova et al. 2016). In the case of the S1 and S2 sites, S1 is the nearest site to S2, S1 is located more in the upper part of the watershed than S2. The clustering clearly showed a separation of the two sites. Although they share the same watershed, the rotifer community of both sites were different. The S1 was separated from S2 due to the dry period in winter and summer seasons. However, the presence of two *Elaphoidella* species (harpacticoid copepods) in S1 and S2 that were not observed at other sampling sites and have never previously been observed elsewhere in Thailand (Boonyanusith & Athibai 2014), is an indication of the connection between S1 and S2. The cluster analysis also revealed that, in the rainy season, S1 and S2 are grouped together, which is supported by the similarity of their rotifer assemblages. S2 could be classified as a relatively large reservoir, and its water level was stable throughout the three sampling occasions. This characteristic supports the continual presence of macrophytic vegetation in the reservoir's littoral zone, in turn ensuring the presence of stable rotifer microhabitats and hence its high diversity of rotifers.

The CCA triplot showed the effects of electrical conductivity, total dissolved solids, ammonia, nitrate, orthophosphate and altitude on the distribution of the rotifer species in the inland waters of the SERS. *Anuraeopsis fissa*, *Brachionus kostei*, *Polyarthra vulgaris,* and *Trichocerca pusilla* were predominant at S3 and S4 in the rainy and summer seasons, with relatively high values for those variables. Conde-Porcuna et al. (2002) reported that the population of *Anuraeopsis fissa* correlated with the soluble reactive phosphorus value in a mesotrophic reservoir in southern Spain. Based on the DO levels and water temperature, the CCA result indicated that DO seems to be an influential factor for *Filinia longiseta*. This species was found to be most abundant in the rock pool of the intermittent stream (S5) in the rainy season (9.13mg/l of DO), whereas *Filinia opoliensis* and *Trichocerca similis* were predominant at the reservoir (S2) in summer, when water temperatures there were at their highest (30.4^{0}C). Similarly, Negreiros et al. (2010) pointed out that pH, EC and DO probably influenced the fluctuations in the rotifer population in the Sapucaí River arm of Furnas Reservoir, MG, Brazil. Sharma (2010) reported that variations of rotifer communities in a Ramsar site, namely Deepor Beel in India were influenced by several factors such as rainfall, water temperature, transparency, EC, DO and PO_4^3. Furthermore, Sulehria et al. (2012) found that water temperature, EC, DO, pH and TDS affected the rotifer assemblages in floodplains at Dhan, Pakistan; however, some rotifer species showed a negative correlation with major factors: *Brachionus quadridentatus*, *Lecane bulla*, *L. curvicornis,* and *Mytilina acanthophora* were dominant at sites with low values for DO and water temperature, and *Keratella tropica* had a high density at sites with low values for EC, TDS, NH_3, NO_3^-, PO_4^{3-} and altitude. The results indicate that seasonal changes are important factors affecting the environmental factors, seasonal distribution and seasonal succession in the community of rotifers at each sampling site in the SERS.

CONCLUSİON

The investigation of the monogonont rotifers, regarding differences found in both seasonal and habitat types, provides a detailed description of the seasonal variation found within species assemblage, abundance, and responses to water quality, as well as, the critical factors which result in their distribution throughout the SBR. Seventy-one rotifers were recorded in this study with 36.6% of these composed of lecanid rotifers. The species richness of rotifers was highest during the rainy season. The largest habitat type was the reservoir which also had the highest number of rotifers present. The dominant species in each of the sampling sites were *Lecane bulla*, *Polyarthra vulgaris,* and *Trichocerca similis.* Certain species which showed importance were *Filinia longiseta* which had a maximum density in the intermittent stream during the rainy season and *Brachionus quadridentatus* which showed the highest numbers present in the pond during the winter season. In addition to this, the physicochemical parameters of the water data are similar to those found in natural water bodies throughout conservation areas of Thailand.

Water temperature, pH, transparency, ammonia, and electrical conductivity were found to have both seasonal and spatial fluctuations. The low pH found in the intermittent stream during the summer season resulted in the highly acidic stream found here. Overall, seasons, habitat types, connectivity and location of sampling sites, as well as the environmental factors such as water temperature, dissolved oxygen, electrical conductivity, total dissolved solids, nitrate, orthophosphate, ammonia and altitude strongly influenced the differences found among the rotifer community structure in inland waters of the SBR. To conclude, further studies are required particularly with regard to crustacean zooplankton in order to gain further knowledge on the overall zooplankton biodiversity found in Thailand.

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COMMUNICATION

Distribution and habitats of *Paphiopedilum* Pfitzer (Orchidaceae) known to occur in Bhutan

Dhan Bahadur Gurung [1], Nima Gyeltshen [2], Kezang Tobgay [3], Stig Dalström [4], Jangchu Wangdi [5], Bhakta Bahadur Ghalley [6], Lekey Chaida [7], Phuntsho [8], Ngawang Gyeltshen [9], Kelzang Dawa [10], Tandin Wangchuk [11], Rebecca Pradhan [12], Thomas Hoijer [13] & Choki Gyeltshen [14]

[1] College of Natural Resources, Royal University of Bhutan, Lobesa, Bhutan.
[2–4,14] National Biodiversity Centre, Ministry of Agriculture and Forests, Serbithang, Thimphu, Bhutan.
[4] 2304 Ringling Boulevard, unit 119, Sarasota FL 34237, USA.
[4] Lankester Botanical Garden, University of Costa Rica, Cartago, Costa Rica; and the National Biodiversity Centre, Serbithang, Thimphu 11001, PO. Box. 875 Bhutan.
[5–11] Department of Forests and Park Services, Ministry of Agriculture and Forests, P.O. Box. 1345, Thimphu 11001, Bhutan.
[12] Royal Society for Protection of Nature, P.O. Box. 325. Lhado Lam, Kawajangsa, Thimphu, Bhutan.
[13] Dackelvagen 59A, 17758 Jarfalla, Sweden.
[1] dbgurung.cnr@rub.edu.bt, [2] nimss409@gmail.com (corresponding author), [3] zangtobgyeel14@gmail.com, [4] stigdalstrom@gmail.com, [5] jwangdi22@gmail.com, [6] bbghalley2000@gmail.com, [7] lekicheda@yahoo.com, [8] phuntshow125@gmail.com, [9] ngawanggyeltshen@moaf.gov.bt, [10] keldendawa2012@yahoo.com, [11] twangchoks@gmail.com, [12] rebecca.pradhan@gmail.com, [13] hoeijeri@gmail.com, [14] chokig@gmail.com

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Abstract: *Paphiopedilum fairrieanum*, *P. spicerianum*, and *P. venustum* (Orchidaceae: Cypripedioideae) are reported to occur in Bhutan, of which the former is known to be Critically Endangered and the latter two are Endangered. Based on numerous field trips conducted over the last decade, populations of *P. fairrieanum* and *P. venustum* were located in Bhutan. No individual of *P. spicerianum*, however, was found despite many search attempts. Its occurrence in Bhutan may have been originally erroneous. Based on the accessibility of the habitats, six 10m × 10m quadrats were defined to enumerate the plant species found in the *Paphiopedilum* habitats. Vegetation analyses and cluster dendrograms of the plant species composition indicated the presence of three forest types with distinct species compositions. *Paphiopedilum fairrieanum* was found growing mainly as a lithophyte on seasonally dry limestone cliffs or on limestone outcrops with a comparatively open forest canopy. These populations were mostly located on southwest- or northwest-facing slopes with soil pH ranging from 7.1 to 7.8. *Paphiopedilum venustum*, in contrast, was a ground-dwelling species restricted to relatively dense forests with soil pH ranging from 7.1 to 7.5.

Keywords: Cluster dendrogram, eastern Himalaya, orchid, *Paphiopedilum fairrieanum*, *P. spicerianum*, *P. venustum*, vegetation analysis.

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INTRODUCTION

More than 70 species of *Paphiopedilum* Pfitzer (Orchidaceae: Cypripedioideae) are reported from southeastern Asia, India, Myanmar, southwestern China, Indonesia, the Philippines, New Guinea, and the Solomon Islands (Pearce & Cribb 2002). Distribution ranges for some species extend to the eastern Himalaya, including Bhutan, India, and Nepal. Pradhan (1976) reported the occurrence of *P. fairrieanum* (Lindl.) Stein and *P. venustum* (Wall. ex Sims) Pfitzer in Bhutan. Pearce & Cribb (2002), however, reported *P. fairrieanum* and *P. spicerianum* (Rchb. f.) Pfitzer from Bhutan, but not *P. venustum*. All these three *Paphiopedilum* species are listed in the IUCN Red List as either Endangered or Critically Endangered and are considered possibly extinct in Bhutan (Rankou & Kumar 2015a,b; Rankou & Molur 2015).

Paphiopedilum fairrieanum (Critically Endangered) is reported from Surelakha in Sarpang District (Pearce & Cribb 2002), Gomdar in Samdrup Jongkhar District (Gurung 2006), and Kalikhola in Dagana District (Dorji 2008). Recent surveys, however, indicate that *P. fairrieanum* is no more found in Surelakha. Consequently, the Bhutanese researchers, academics, foresters, and volunteers who have begun to study orchids have expanded their search for new populations of the species outside the recorded localities.

In addition to being considered possibly extinct in Bhutan (Rankou & Kumar 2015a,b; Rankou & Molur 2015), very little is known about the distribution ranges, habitat preferences, and population structures of the *Paphiopedilum* species known to occur in the country. Using the information generated from several explorations, this paper provides the current occurrence status of these *Paphiopedilum* species and the vegetation composition of their habitats.

MATERIALS AND METHODS

The team conducted a series of orchid expeditions over the last decade. Habitat information provided by researchers allowed confirmations of *Paphiopedilum* species in the reported areas. Vegetation surveys were conducted in a few selected areas in 2016, based on the accessibility of the habitats. A total of 13 quadrats of 100m^2 was laid out in different locations and among the 13 plots, six quadrats of 10m × 10m where the *Paphiopedilum* species occur were surveyed to assess the vegetation composition, habitat quality, and species richness of these sites: three in Zhemgang, two in Mongar, and one in Samdrup Jongkhar. In the tree category, diameters at breast height (DBH) at 1.3m above the ground were measured to determine the basal area. On the forest ground, subplots of size 2m × 2m were laid out for herbs, and the height of the tallest of each species and their corresponding coverage were recorded. Soil pH was measured by using Takemura Digital pH meter. Species basal area (BA) was calculated from DBH data of all the tree individuals and the relative proportion of the basal area of each species was calculated in percentage (RBA). Species diversity index (H) was calculated using the Shannon & Wiener equation. The processed data were then analyzed by using PC-ORD version 5.1 program. Cluster analysis was performed using the distance measure of Sorensen (Bray-Curtis) with group linkage method to determine the forest types of the *Paphiopedilum* habitats (Ohsawa 2002; Dorji et al. 2014).

RESULTS AND DISCUSSION

Distribution range of *Paphiopedilum fairrieanum*

The occurrence of *Paphiopedilum fairrieanum* (Lindl.) Stein in Bhutan was reported by Pradhan (1976) and Pearce & Cribb (2002). Regionally, *P. fairrieanum* (Lindl.) Stein is found in Nepal (Raskoti & Ale 2011), India (Sikkim, Arunachal Pradesh, and Assam) (Raskoti & Ale 2011), and Bhutan (Pradhan 1976, 1978, 1996; Chowdhery 1998; Cribb 1998; Pearce & Cribb 2002; Rankou & Kumar 2015a). *Paphiopedilum fairrieanum* in Bhutan was reported to be widely distributed in the limestone formations and outcrops of subtropical forests. Populations were found in Leptshanangra under Mongar District (over 1,000 individuals) spread over more than 5ha at 1,200–1,400 m (Pradhan 1978); in Gomdar under Samdrup Jongkhar District (around 800 individuals); in Kalikhola (Dorji), where only a few plants remain (30 individuals); near Ngangla Trong under Zhemgang District, where *P. fairrieanum* co-occurs (60 individuals) with *P. venustum* and hence there is a potential for the existence of the natural hybrid *Paphiopedilum* x *pradhanii* Pradhan; in Gomtu under Samtse District, which is divided into two subpopulations, one spread over 1ha at 800m (80 individuals) and the other spread over 1.2ha at 1,400m (over 150 individuals); in Sarjung under Samdrup Jongkhar District (1,050 individuals); and in Kheng-Gongdu under Mongar District, of which one subpopulation is spread over more than 3ha at 978m (over 1,000 individuals) and the other is spread over 15ha at 1,044m (over 1,200 individuals according to the authors research data and distribution range, and

population dynamics).

Paphiopedilum fairrieanum was also reported from Pabji in Lamoizingkha (Dagana District) (Dorji 2008), supposedly a good habitat but highly threatened due to poaching. Twenty variously-sized individuals were observed by Gurung et al. (2016). This species co-occurred with *P. venustum*, but the latter is now known to be extinct from this site. Near Aalay in Chukha, however, six individuals of *P. fairrieanum* were observed fruiting. There is still uncertainty over the possible recovery of these two populations. Two populations of *P. fairrieanum* were known to be destroyed in 2016 during a farm road construction. Similarly, another population in Sarjung in Samdrup Jongkhar is likely to be destroyed by a farm road. No plant was recorded from Surelakha in Gelephu District during a current survey as reported by Pearce & Cribb (2002).

Since Chumbi Valley from which *P. fairrieanum* was reported (Pearce & Cribb 2002) is on the other side of the international border, Bhutanese explorers were not able to confirm the presence of the species in the area. Since the valley is connected to Bhutan through Amo Chhu River, however, it is likely that the species is distributed in the subtropical region of Amo Chhu as well.

Distribution range of *Paphiopedilum venustum*

Paphiopedilum venustum (Wall. ex Sims) Pfitzer is known to occur in Nepal (Raskoti & Ale 2011), India (Sikkim and Arunachal Pradesh) (Hooker 1894; King & Pantling 1898; Pradhan 1976; Chowdhery 1998), and China (Tibet) (Govaerts et al. 2019). While Pradhan (1976) reported the occurrence of *P. venustum* from Bhutan without any specific location, Pearce & Cribb (2002) and Gurung (2006) did not confirm its occurrence in Bhutan. *Paphiopedilum venustum* was reported from Kalikhola, Chhukha District (over 20 individuals) by Dorji (2008), from where some plants were also cultivated at the Royal Botanical Garden, Serbithang; from Bjoka and Ngangla under Zhemgang District (over 40 individuals) in 2009 at 1100m; and from Ngangla Village (over 15 individuals) in 2016 at 800m. Also, according to the author's studies/ research data and research information and data will made available soon through Bhutan Biodiversity Portal (www.biodiversiy.bt). This study site is the only habitat where both *P. fairrieanum* and *P. venustum* coexist (Image 1).

Pabji site which was known to harbour both *P. fairrieanum* and *P. venustum* (Dorji 2008) is now devoid of the latter. Similarly, a healthy population of *P. venustum*

Image 1. *Paphiopedilum fairrieanum* and *P. venustum* growing side by side, Ngangla, Zhemgang.

near Bjoka in Zhemgang was completely wiped out by a farm road.

Paphiopedilum spicerianum—possibly extinct in Bhutan

A quote from the past adds credibility and vividly illustrates the degree of never-ending human destruction of our natural resources: "After no small amount of personal hardship this shipment [of wild collected plants of *Paphiopedilum spicerianum* in Bhutan] reached Steven's Auction Rooms on March 9, 1884 in a quantity of 40,000 plants…" (Fowlie 1970). This depicts the intensity of threat these extraordinary plants faced in the past and hence there is a chance that the species had been present in Bhutan but was extirpated to extinction. Pearce & Cribb (2002) added this species to the flora of Bhutan based on the note by Fowlie (1970). This species was not found in the country during the rigorous surveys in the past decade. Excluding Bhutan, this species was reported from northeastern India, Myanmar, and southwestern China.

General characteristics of *Paphiopedilum* habitats

Due to the rise of the Himalaya from the Tethys Ocean (Gansser 1983), there are several limestone rock formations in Bhutan. Many of these formations seem to host *Paphiopedilum* populations. So far, 10 populations of *P. fairrieanum* and four populations of *P. venustum* were recorded in Bhutan. Survey plots were laid where Paphiopedilum species occurred and the vegetation composition in these sites were assessed in Zhemgang, Mongar and Samdrup Jongkhar (Table 1).

The soil pH in these habitats ranged from 7.1 to 7.8. While Pearce & Cribb (2002) mentioned that *P. fairrieanum* is found on limestone, Pradhan (1976) noted that *P. fairrieanum* occurs on gneiss ledges. There is no mention of the occurrence of *P. venustum* in association with limestone formations by Pearce & Cribb (2002) and Pradhan (1976). Except in the case of Ngangla-2, both *P. fairrieanum* and *P. venustum* were found growing sympatrically. In the study area, *P. venustum* grows both in dense broadleaved forests with closed canopies and in limestone dominated areas with soils rich in humus (Image 2) and leaf litter, sometimes mixed with limestone gravel.

A small population of *P. fairrieanum* in Meden faces a strict northern direction. *Paphiopedilum fairrieanum* plants are predominantly found on steep slopes ranging from 65º to 95º (Table 1). The lowest gradient (45º) recorded was from Samtse. *Paphiopedilum fairrieanum* was also observed on overhanging vertical cliffs (>100º), as in the case of the remaining population near Pabji. Growing on more or less vertical cliffs protects the plants from grazing cattle and wild ungulates like Himalayan Goral and, to various degrees, from collection by people and from forest fires.

The lowest altitudinal record of a *P. fairrieanum* habitat is near Aalay at about 600m and the highest known is in Mongar at 1,400m. Pearce & Cribb (2002), however, noted the altitude range of *P. fairrieanum* to be between 1,400m and 2,200m. This suggests that the search for *P. fairrieanum* in Bhutan should extend to

Image 2. *Paphiopedilum venustum* growing on humus rich leaf litter, Kaktong, Zhemgang.

Table 1. Plots showing important parameters of *P. fairrieanum*.

Location (Plots)	Ngangla-1	Ngangla-2	Kaktong	Gongdu	Meden	Sarjung
Altitude (m)	1052	1038	801	1044	978	981
Aspects (º)	NW 25	NW 30	SW 15	N/NE 20	NW 10	NW 25
Inclination (º)	65	70	95	75	95	85
Total BA/ha (m^2/ha)	63,317.71	63,128.08	63,929.38	32,270.58	65,521.85	70,969.68
Diversity index (H')	2.34	2.20	1.69	2.25	2.64	2.06
Species richness (SR)	41	27	25	35	35	39
Soil pH	7.8	7.1	7.5	7.7	7.8	7.5

higher elevations as well. We, however, could not locate any habitat of *P. fairrieanum* in higher elevations. For *P. venustum*, the altitude range in Bhutan varies from about 800m to 1052m (-1,100m). This is higher than the range (300–800 m) mentioned by Pradhan (1976).

Vegetation composition in *Paphiopedilum* habitats

Based on the relative basal area (RBA%) occupied by each species in each plot, the vegetation composition of the habitats were classified into evergreen trees, evergreen shrubs, deciduous trees, deciduous shrubs, and perennial herbs and shrubs (Table 2). Overall, there were 106 plant species belonging to 59 families, among which five species could not be identified. The highest plant diversity in the *Paphiopedilum* habitats was found in Meden with H'=2.64, followed by Ngangla-1 with H'=2.34. Species richness was highest (SR=41) in Ngangla-1 with 33 families and lowest (SR = 25) in Kaktong with 18 families.

Ngangla-1 primarily consisted of evergreen trees with *Phoebe lanceolata* having the highest RBA of 28.865%, *Cinnamomum impressinervium* with RBA of 12.165%, and the deciduous tree *Toxicodendron succedaneum* with RBA of 17.754%. The RBA of *P. fairrieanum* in this site was 0.022%, the lowest among all the habitats assessed. This indicates that the evergreen forest is not well-suited for *P. fairrieanum*. The presence of this orchid in this forest could have been supported by deciduous tree species like *Toxicodendron succedaneum, Celtis tetrandra, Dalbergia sericea*, and *Kydia calycina* which allowed sunlight to reach the ground. It is possible that this population together with the Ngangla-2 population represent outgroups that originated from a larger and healthier population that is locally rumoured to exist nearby.

Ngangla-2 harbours both *P. fairrieanum* and *P. venustum* (Image 1). The evergreen trees in this forest include *Rapanea capitellata* (RBA=28.998%) and *Acer oblongum* (RBA=18.112%). RBA of *P. fairrieanum* was 0.024% and that of *P. venustum* was 0.034%. The Kaktong site, however, had *P. venustum* (RBA=0.102%) population under *Kydia calycina*, a deciduous tree species with the highest RBA of 49.142% followed by *Picrasma* sp. (RBA=20.120%) and *Dysoxylum* sp. (RBA=10.855%), which are both evergreen tree species. Total RBA of evergreen tree species in Ngangla-1, Ngangla-2, and Kaktong habitats were 67.376%, 63.430%, and 47.771%, respectively. Likewise, the RBA of evergreen tree species in Meden was 47.468%. The Gongdu and Sarjung habitats, however, have higher RBA of evergreen shrubs than tree species with 31.039% and 52.443%, respectively. The Gongdu, Meden, and Sarjung habitats have unidentified bamboo species with RBA of 41.834%, 24.419%, and 14.091%, respectively.

An analysis of the vegetation composition using PC-ORD indicated that there were three types of forests in the *Paphiopedilum* habitats assessed (Fig. 1). Ngangla-1 and Ngangla-2 had forests dominated by *Cinnamomum*, *Rapanea*, *Toxicodendron*, *Acer*, and *Phoebe* species. Gongdu, Meden, and Sarjung had a forest dominated by *Quercus, Acer, Diploknema, Albizia, Desmodium, Colebrookea*, and *Neyraudia*. The Kaktong habitat was dominated by *Dysoxylum*, *Picrasma*, and *Kydia* tree species.

All the *Paphiopedilum* habitats had a considerable proportion of evergreen trees or evergreen shrub species (Table 2; Fig. 2). In the lower altitudes, especially in Kaktong, there was almost an equal proportion of deciduous and evergreen species. All the tree and shrub species noted in these sites, however, are not necessarily the indicators of the presence of *Paphiopedilum* populations, yet the general forest types may give some idea of the possibility of finding *Paphiopedilum* species. Especially for *P. fairrieanum*, the presence of limestone is critical (Image 3).

Threats to *Paphiopedilum* habitats

Rankou & Kumar (2015a,b) mentioned forest fire, illegal collection for trade and horticulture, human disturbance, trampling by cattle, deforestation, climate change, and intrinsic factors as the main threats to *Paphiopedilum* species in their natural habitats. In Pabji, the local people who collected *P. fairrieanum* for the

Image 3. *Paphiopedilum fairrieanum* growing on limestone cliff, Ngangla, Zhemgang.

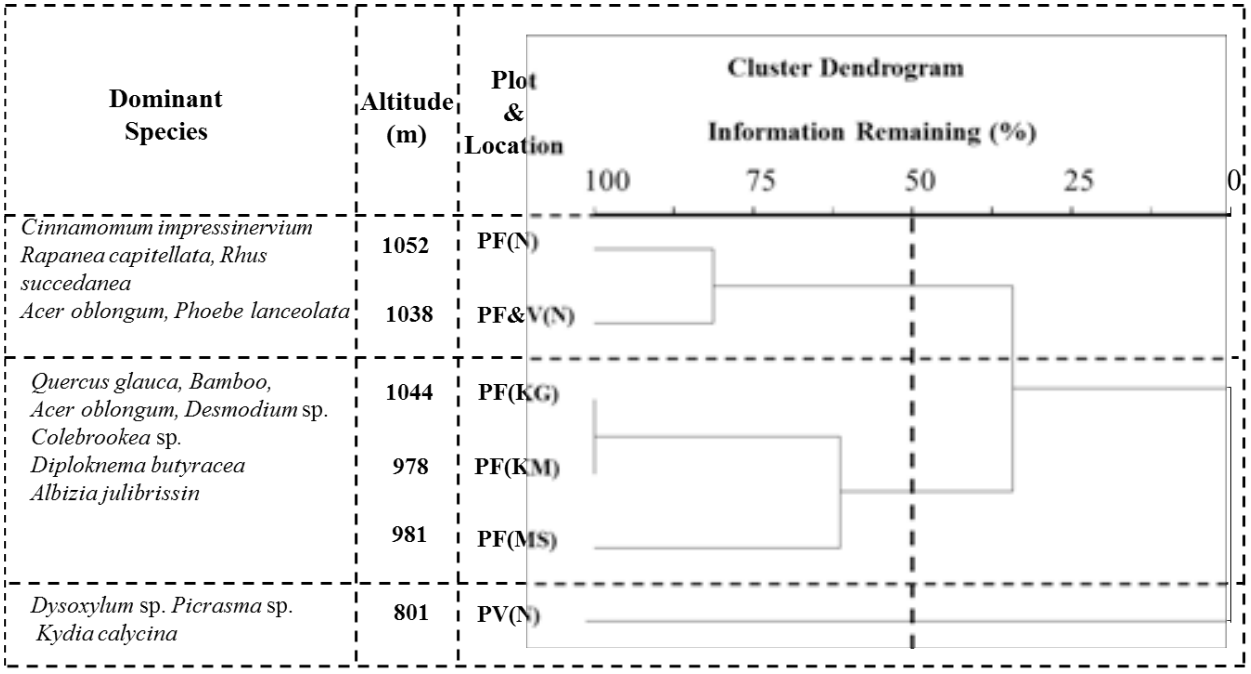

Figure 1. Dendrogram showing three forest types supporting *Paphiopedilum* populations.
Note: PF(N) = Ngangla-1 | PF&V(N) = Ngangla-2 | PF(KG) = Gongdu | PF(KM) = Meden | PF(MS) = Sarjung | PV(N) = Kaktong.

collectors in the 1960s and 1970s said that *P. fairrieanum* is grazed by wild ungulates such as the Himalayan Goral. We, however, did not observe such incidents in any *Paphiopedilum* population. There were, however, signs of forest fire damage in the upper population sites of *P. fairrieanum* in Samtse.

Since 2008, farm road construction in Bhutan has picked up very fast. Farm road construction generally follows traditional footpaths. A healthy population of *P. venustum* near Djoka was completely destroyed by a recent farm road construction. Similarly, in 2016, a farm road was constructed right through the lower population site of *P. fairrieanum* in Samtse and thus we could not locate a single remaining individual of *P. fairrieanum*. A farm road was also constructed through the *P. fairrieanum* population at Sarjung.

Paphiopedilum fairrieanum seems to prefer seasonally dry slopes prone to forest fires. Since most of the remaining populations are found on steep slopes of up to 95–100 °, forest fires may not be able to destroy plants that grow on overhanging limestone cliffs. As areas warm up due to climate change and fuel loads accumulate due to forest fire control, however, any fire outbreak in *Paphiopedilum* habitats could prove disastrous to the orchid populations. Electricity transmission lines also pass through many of these habitats (Image 4). Hydropower development has also picked up in recent years in Bhutan. The *P. fairrieanum* population in Gomdar could be in risk due to the development of the Nyera-amari Chhu hydropower project.

In general, anthropogenic activities do not seem to be a serious problem as all orchids in Bhutan are protected by the Forest and Nature Conservation Rules and Regulations 2006 (RGoB 2006). There were, however, instances of illegal collections in small quantities even in the early 2000s. Despite strict enforcement of Forest and Nature Conservation regulations to protect these rare orchid species, the risk of illegal collection is still very high as these habitats are easily accessible by roads.

Recommendations

Many of the foresters who are entrusted with the responsibility of protecting the species, however, cannot identify even the critically endangered species. Therefore, educational programs and conservation awareness campaigns may have to be carried out to protect endangered orchids such as the *Paphiopedilum* species. Further explorations and research are recommended to confirm if *P. spicerianum* is found in Bhutan. Environmental impact assessment (EIA) for all farm roads planned will have to be conducted with diligence, especially considering the threatened species. If at all possible, some of the *Paphiopedilum* habitats should be declared as protected areas—'orchid sanctuaries'. The orchid sanctuary should be open to visitors, perhaps for a small fee that will benefit the local

Table 2. Relative basal area (RBA) in % per hectare. The green boxes indicate the dominant species.

Location (plots)	Nangla-1	Nangla-2	Kaktong	Gongdu	Meden	Sarjung
Evergreen trees						
Phoebe lanceolata	27.865	1.686	0.276	1.025	5.418	0.692
Cinnamomum impressinervium	12.165	1.524	0.266			
Acer oblongum	10.490	18.112			10.818	2.342
Euonymus sp.	5.241		1.592			
Dysoxlum sp.	3.354		10.855			
Diploknema butyracea	2.740	0.280		0.294	7.293	1.356
Skimma sp.	1.384		1.888			
Combretum sp.	0.984					
Pandanus furcatus	0.972	0.756	0.208			0.488
Rapanea capitellata	0.908	28.998			3.759	
Miliusa roxburghiana	0.496					
Cinnamomum sp.	0.474					5.269
Ficus heteropleura	0.179					
Talauma hodgsonii	0.124	0.080			2.961	2.162
Wendlandia grandis		11.949		0.930		0.585
Hyptianthera stricta		0.045				
Picrasma sp.			20.120			
Aglaia korthalsii			5.982			
Sphaerosacme decandra			3.716			
Lithocarpus dealbatus			1.294			
Persea sp.			1.181			0.217
Elaeocarpus sp.			0.393			
Bridelia retusa				1.073		
Stereospermum colais				0.585		
Quercus glauca					11.512	1.403
Pinus roxburghii					5.707	
Castanopsis hystrix						3.852
Neocinnamomum caudatum						0.585
Subtotal	67.376	63.430	47.771	3.907	47.468	18.951
Evergreen shrubs						
Desmodium sp.	0.126	0.634		1.394	0.916	50.303
Capparis assamica	0.079					
Maesa chisia	0.079					
Leea asiatica	0.031					
Murraya paniculata			0.595			
Croton sp.			0.213			
Tabernaemontana divaricata			0.123			
Colebrookea sp.				19.367	1.526	
Reinwardtia indica				3.099	0.740	0.240
Woodfordia fruticosa				1.859	0.992	0.845
Daphne bholua				1.549	0.238	
Holmskioldia sanguinea				1.549		
Osyris lanceolata				1.240		

Location (plots)	Nangla-1	Nangla-2	Kaktong	Gongdu	Meden	Sarjung
Rhus paniculata				0.477	1.386	
Hypericum sp.				0.279		
Viburnum cylindricum				0.193	0.690	
Indigofera dosua				0.032		
Luculia gratissima						1.055
Subtotal	0.316	0.634	0.930	31.039	6.488	52.443
Deciduous trees						
Toxicodendron succedaneum	17.754	9.412				2.826
Celtis tetrandra	0.126					1.279
Dalbergia sericea		9.417				
Kydia calycina			49.142			
Rhus chinensis				0.079	3.626	
Albizia julibrissin					8.948	
Bauhinia purpurea					2.536	0.601
Engelhardia spicata						3.348
Subtotal	17.881	18.829	49.142	0.079	15.111	8.054
Deciduous shrubs						
Fluggea virosa			0.141			
Spiraea sp.				6.198		
Subtotal	0.000	0.000	0.141	6.198	0.000	0.000
Perennial herbs & shrubs						
Strobilanthes sp.	1.421	0.348	0.034	1.240	0.687	0.557
Neyraudia sp.	1.406	3.168	0.267	41.834	24.419	14.091
Oplesminus sp.	0.711	0.396		2.324	1.221	1.071
Eranthemum sp.	0.671	0.260				
Carex sp.	0.316					0.189
Hedychium sp.	0.316					0.007
Jasminum grandiflorum	0.197	1.742				
Piper sp.	0.166				0.082	
Smilax sp.	0.152		0.250	0.341	0.229	0.220
Thysanolaena latifolia	0.122				0.366	0.366
Menispermum sp.	0.077			0.124	0.046	0.017
Begonia sp.	0.073	5.608			0.435	0.232
Agrostemma sp.	0.052					
Ehretia sp.	0.045					
Tectaria sp.	0.033		0.547			
Malaxis sp.	0.032					
Clematis sp.	0.025	0.008		1.240	0.153	0.282
Paphiopedilum fairrieanum	0.022	0.024		1.162	0.397	0.282
Boehmeria sp.		3.802				
Phyllanthus sp.		1.584				0.220
Paphiopedilum venestum		0.038	0.102			
Adenostemma sp.		0.025				
Elatostema sp.		0.025				
Tetrastigma sp.			0.782			

Location (plots)	Nangla-1	Nangla-2	Kaktong	Gongdu	Meden	Sarjung
Pogonatherum crinitum				2.324		0.273
Duhaldea cappa				2.014		
Apluda mutica				1.704		
Jasminum sp.				1.549	0.839	1.691
Boenninghausenia albiflora				0.837		
Cymbopogon sp.				0.697		
Barleria cristata				0.620	0.244	
Asparagus filicinus				0.583		
Swertia sp.				0.155		
Hemidesmus sp.				0.031	0.012	
Drepanostachyum intermedium					0.916	
Senecio sp.					0.511	
Lindenbergia grandiflora					0.238	
Commelina sp.					0.069	
Rubus sp.					0.069	
Arundina graminifolia						0.845
Eria biflora						0.068
Bulbophyllum sp.						0.051
Spathoglottis sp.						0.042
Dendrobium chrysanthum						0.039
Goodyera sp.						0.010
Subtotal	4.430	13.861	1.716	16.944	6.514	6.462
Unidentified species						
Fern 1	8.292					
Fern 2	0.221					
Unknown 1	0.079					
Unknown sp.		0.079	0.011			
Fern sp. 1			0.022			
Subtotal	9.997	3.247	0.300	41.834	24.419	14.091
Grand total	**100**	**100**	**100**	**100**	**100**	**100**

people. Local people living near *Paphiopedilum* habitats may be given the responsibility to protect the species and will hopefully benefit from the sanctuary. Such programs, however, should be fully supported and supervised by the Department of Forest and Park Services and other relevant agencies.

CONCLUSION

Three *Paphiopedilum* species have been reported from Bhutan: *P. fairrieanum*, *P. venustum*, and *P. spicerianum*. Several populations of *P. fairrieanum* and two small populations of *P. venustum* were recorded during this study. A few populations of *P. fairrieanum* seem to extend over 15ha. While *P. fairrieanum* seems to grow in large colonies, individuals of *P. venustum* were found with fewer and scattered individuals in each site, often represented by a single growth. *Paphiopedilum fairrieanum* seems to prefer rather exposed limestone formations with open canopy forest, receiving plenty of sunshine. This species mainly prefers northwest- to southwest-facing slopes and commonly occurs on more or less vertical, sometimes overhanging cliffs. *Paphiopedilum fairrieanum* prefers soil and rocky limestone outcrops with a pH of 7.1–7.8. In contrast, *P. venustum* commonly grows among leaf litter and in shallow humus-rich soils sometimes mixed with limestone gravel and in deep forests with a closed canopy. *Paphiopedilum spicerianum* has not been documented

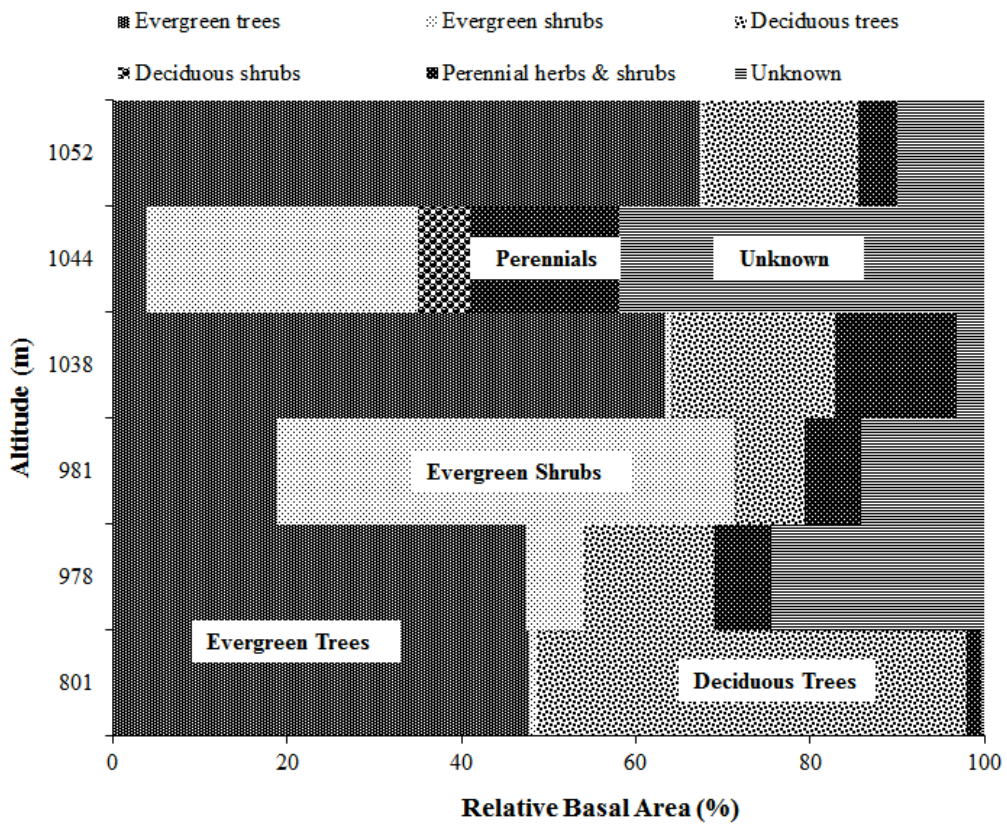

Figure 2. Various categories of vegetation composition found in the *Paphiopedilum* habitats in Bhutan.

Image 4. *Paphiopedilum fairrieanum* habitat with power lines passing over a foot path, Gongdu, Zhemgang.

so far or reported in recent times by current orchid explorers. Therefore, more efforts should be conducted to ascertain the occurrence of this species in Bhutan.

Many *Paphiopedilum* populations in Bhutan are threatened by farm road constructions. Limited collections of a few plants for research and conservation purposes also occur but deleterious collections of *Paphiopedilum* species in Bhutan seem to have occurred in the 1960s and 1970s, wiping out some populations completely. Impacts of forest fire and climate change on the species are poorly understood. Further work is required to search for potential *Paphiopedilum* habitats, especially in southeastern Bhutan. Education and conservation awareness programs for forest officials and local communities in the country may prove useful. Perhaps, a few habitats can be declared orchid sanctuaries to protect the endangered species while also benefiting the local communities.

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Author details: Dhan Bahadur Gurung is a Professor of Natural Resources. He is currently conducting research in orchid taxonomy and also exploring fish diversity in Bhutan. Nima Gyeltshen currently works on conservation of native flora at the Royal Botanic Garden Serbithang, Thimphu under the National Biodiversity Centre. He is interested in studying orchid taxonomy and plant diversity and ecology. Kezang Tobgay also works on the conservation of native floral species at the Royal Botanic Garden Serbithang, Thimphu under the National Biodiversity Centre. He is interested in studying orchid taxonomy and ecology, and plant diversity. Stig Dalstrom is studying the orchid taxonomy in Bhutan and South America. Jangchuk Wangdi is involved in forest management and is also working on the taxonomy and diversity of orchid species in Bhutan. Bhakta Bahadur Ghalley works for the forest management and is also working on orchid diversity and ecology and also on other biodiversity taxonomic groups. Lekey Chaida is involved in park management and he has diverse interests such as orchids, other plant families, fishes, amphibians and reptiles, and many more. He is involved in field research related to forest and biodiversity. Phuntsho is involved in the management of park, and has developed his interest in orchid taxonomy and diversity. He is involved in field research related to forest and biodiversity. Ngawang Gyeltshen looks after the flora section of the Forest Department. He is involved in the inventory and guidance of floral study which is aligned with the mandates of forest department. He is also studying orchid and other plant diversity. Kelzang Dawa looks after the forest nursery and is also involved in studying the plant taxonomy and diversity. Tandin Wangchuk works with the forest management in the eastern Bhutan. He has vast interest in studying different biodiversity taxonomic groups such as plants, butterflies, birds, etc. He is also involved in field research related to forest and biodiversity. Rebecca Pradhan studies the ecology of certain biodiversity taxonomic groups such as plants and birds. She has vast experience in the study of floral species in Bhutan. Thomas Hoijer is involved in maintaining and designing of the Orchid House at Royal Botanic Garden Serbithang, and he also participated in the field works and collection of both live and herbarium orchid specimens in Bhutan. Choki Gyeltshen is working on the management of national biodiversity information system including the Bhutan Biodiversity Portal (www.biodiversity.bt). He is involved in studying orchid taxonomy and diversity.

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PLATINUM
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Diurnal *Serianthes nelsonii* Merr. leaflet paraheliotropism reduces leaflet temperature, relieves photoinhibition, and alters nyctinastic behavior

Thomas Edward Marler

Western Pacific Tropical Research Center, University of Guam, Mangilao, Guam 96923, USA.
thomas.marler@gmail.com

Abstract: The diel cycle of *Serianthes nelsonii* leaflet movements was characterized under four levels of shade from full sun to 22% sunlight transmission to determine the photoprotective components of diurnal leaflet movements and the relationship to patterns of nocturnal leaflet movements. Treatments also included negating paraheliotropism by re-orienting plants every 15min throughout the photoperiod such that the plants never experienced a predictable solar vector. The timing of leaflet closure to avoid high light, the shape of the diurnal curve depicting leaflet angle, and the maximum extent of leaflet closure were influenced by the shade treatments. Protection of leaf function by paraheliotropism was also influenced by shade treatment, with the full sun plants exhibiting the greatest level of protection. Leaflet heat gain was reduced 50% by leaflet movement as determined by direct measurements of leaf-to-air temperature differences. Midday quantum efficiency of photosystem II was increased 120% by leaflet movement as determined by direct measurements of pulse modulated chlorophyll fluorescence. The extent of nyctinastic leaflet closure was greatest in the high light plants that moved the most midday and least in the shaded plants that moved the least midday, indicating the extent of diurnal paraheliotropism controlled the amplitude of nocturnal leaflet movement. *Serianthes nelsonii* is highly skilled at using movement to reduce leaflet exposure to the solar vector, providing instantaneous behavioral control over heat gain and photoinhibition. This case study of an endemic tree species in Micronesia has added to the nascent field of conservation physiology, and indicated that heliotropism of *S. nelsonii* leaves may provide the species with the ability to minimize high light damage during increased temperatures associated with climate change.

Keywords: Chlorophyll fluorescence, conservation physiology, Fire Tree, Guam, pulvinus.

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Author details: Thomas Edward Marler is a professor with the University of Guam. He has an interest in conservation of native plants in the Western Caroline Islands, the Mariana Islands, and the Philippine Islands.

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INTRODUCTION

Serianthes nelsonii is a legume tree endemic to the two southernmost islands of the Mariana Island archipelago. Many legume species are equipped with pulvini at the base of leaflets or leaves which enable rapid leaf movements. General observations of this plant reveal the leaves exhibit this characteristic legume leaf response of diurnal and nocturnal leaflet movements, indicating the location of a pulvinus at each petiolule. The tree is known locally as 'Hayun Lagu' in the United States Territory of Guam and 'Tronkon Guafi' in the United States Commonwealth of the Northern Mariana Islands (USFWS 1987). The species is listed as Critically Endangered by the International Union for Conservation of Nature (Wiles & Williams 2017) and listed as Endangered under the United States Endangered Species Act (USFWS 1987). The need for more research to understand the biology of the species was a prominent component of the 25-year-old species recovery plan (USFWS 1994).

Plant movements can be classified into tropic movements which are controlled by a stimulus vector, and nastic movements which are independent of a directional stimulus (van Zanten et al. 2010). The diurnal movement of *S. nelsonii* leaflets is a tropic behavior, where the movements are employed to adjust to the sun vector throughout the day. The movements that reduce the angle of incidence of the solar beam are referred to as paraheliotropic movements (Ehleringer & Forseth 1980). In contrast, the nocturnal movements of *S. nelsonii* leaflets are nastic movements, as there is no directional stimulus that mediates the movements. These nocturnal leaflet movements are referred to as nyctinastic movements.

Conservation physiology has been described as a sub-discipline of conservation science (Wikelski & Cooke 2006). The benefits of adding conservation physiology to the palette of conservation science agendas is that physiology relies on cause-and-effect mechanisms that are illuminated through empirical approaches (Cooke et al. 2013). The ability to move leaves in response to the solar beam may benefit photosynthesis and carbon gain (Mooney & Ehleringer 1978; Forseth & Ehleringer 1983; Nilsen & Forseth 2018). Therefore, the observations that *S. neslonii* plants are able to move leaflets enabled the potential to add this case study to the paraheliotropism literature within the conservation physiology discipline.

My objective was to determine the diurnal benefits that *S. nelsonii* leaves receive by exploiting paraheliotropic movements of leaflets. This was accomplished with remote measurements of leaf temperature and chlorophyll fluorescence. The quantum efficiency of Photosystem II (ϕPSIIR) is useful for understanding the relative amount of absorbed light that is actually used in Photosystem II photochemistry (Genty et al. 1992; Murchie & Lawson 2013). This photosynthesis trait was employed to determine the level of protection against photoinhibition provided by *S. nelsonii* leaflet movement. I also measured nyctinastic movements to more fully understand how incident light during the day influenced these nocturnal leaflet behaviors.

MATERIALS AND METHODS

Nursery operations

Guam-sourced *S. nelsonii* plants were grown in a container nursery under four levels of incident light to provide 100%, 73%, 38%, or 22% of sunlight. Leaves were allowed to emerge and mature on the plants under each of the incident light levels. The plants were 60–80 cm in height when the leaflet behaviors were monitored in January and February 2015. Guam's weather during these months of the dry season is fairly homogeneous, with a high of 30°C, a low of 22°C, and a mean of 26°C for the duration of the study. A mean of 6.4h of clear sunshine occurred per day, and total photoperiod was 11.3h. The plants were well-watered to avoid drought stress.

Stochastic cloud passage was common for most days of measurement. These clouds reduced incident light in a heterogeneous manner and the duration of each cloud's blockage of the solar beam was also heterogeneous. The results for each of these days were not repeatable due to the heterogeneity of abrupt changes in light due to stochastic cumulus cloud cover. Therefore, I continued to collect data until a clear day and subsequent night occurred on 10–11 Feb 2015.

The movement of the mature leaflets was quantified directly with a protractor approximately every 2h. The angle between a horizontal plane and each leaflet was measured, such that an angle of 90° represented a vertical leaflet and an angle of 0° represented a horizontal leaflet. There were eight plants per shade level, and the leaflet angle measurements were made on three leaflets per plant, for a total of 24 measurements per shade level.

Physiology measurements

The influence of leaflet movement on leaf physiology was studied by re-orienting half of the plants in each

shade treatment every 15min throughout a diurnal period to reverse the benefits of leaflet movement. The plants were placed on their sides on the nursery benches, then returned to a vertical position in an alternating pattern. This approach did not allow the leaflet movement on the treated plant leaves to avoid the natural incidence of the solar beam. The surfaces of the containers were shaded from direct sunlight when the plants were placed sideways during re-orientation to ensure the roots did not experience high temperatures.

The leaflet temperature was measured throughout diurnal periods with an infrared temperature gun (Milwaukee Model 2267-20, Milwaukee Tool, Brookfield, WI, U.S.A.). Accuracy of the infrared thermometer was initially checked by comparing to direct measurements of leaflet temperatures with a thermistor (PP Systems, Amesbury, MA, U.S.A.). The infrared approach was highly accurate for leaflets in all shade levels. There were four plants per treatment within each shade level, and leaflet temperature was recorded for three leaflets per plant for a total of 12 measurements per treatment within each shade level.

Chlorophyll fluorescence was measured with a FMS2 pulse modulated fluorometer (Hansatech, Norfolk, United Kingdom). The ϕPSIIR (Genty et al. 1989; Murchie & Lawson 2013) was quantified without dark-acclimation and during full exposure of the test leaflets to the incident light. The number of measurements was as described for leaflet temperature.

All data were plotted separately for the diurnal and nocturnal period. The influence of shade treatments on diel leaflet behaviors was discussed.

RESULTS

The earliest morning leaflet movement and the most severe leaflet angles occurred on sunny days. Plants exposed to full sun conditions were highly skilled at maintaining a very narrow angle between the leaflet surface and the solar vector (Fig. 1). As the sun increased in height from the east each morning, the leaflets closed to track the angle of the sun. At noon, these leaflets were oriented very close to vertical. As the sun set towards west each afternoon, the leaflets re-opened to track the angle of the sun. Plants in shaded growing conditions also moved in response to incident light, but the amplitude of leaflet movement was muted in comparison to leaves on full sun plants. Plants under 73% light transmission stopped the vertical movements at about 60° above the horizontal before re-opening in the early afternoon. Plants under 38% light transmission were even less in need of protecting themselves with paraheliotropism, so they stopped the movement at about 40^0 above the horizontal before re-opening in the afternoon. Plants in deepest shade moved their leaflets very little throughout the photoperiod, with a maximum of about 23^0 leaflet displacement during midday. The leaflet angle diverged among the shade treatments before 09.00h, and remained divergent until 18.00h.

Plants in all four shade treatments exhibited leaflet movements during the nocturnal period (Fig. 2). The leaflets began to close shortly after sunset, reached a maximum from 02.00–04.00 h, then began to re-open several hours prior to sunrise such that they were almost fully open before 08.00h. The nocturnal pattern and maximum nocturnal leaflet angle differed among the shade treatments, with the full sun and 73% sunlight transmission plants beginning leaflet closure earlier in the night and reaching a maximum angle of 85^0. In contrast, the plants receiving the deepest shade level began leaflet closure later in the night and reached a maximum of only 50^0 before beginning to re-open the leaflets. Synchronized patterns of leaflet movement for all four shade treatments are depicted in the video file (Video 1).

Moving the orientation of plants throughout the photoperiod to negate the benefits of leaflet paraheliotropism exerted a strong influence on leaflet temperature. When plants were allowed to use leaflet paraheliotropism to avoid high light, the leaflet temperatures of full sun plants were maintained to within 4.5^0C above ambient (Fig. 3, left). Interestingly, the paraheliotropism was more effective in reducing leaflet heat gain during midday than in early morning and late afternoon hours. In contrast, the treated full sun plants for which paraheliotropism was negated exhibited a leaf-to-air temperature difference of 8^0C (Fig. 3, right). Moreover, the shape of the diurnal curve was approximately bell-shaped for the treated full sun plants, rather than exhibiting a midday dip as for the control plants. The influence of shade treatments on the shape of the diurnal curve was similar among the three shade levels, but the influence on diurnal leaf-to-air temperature maxima diverged for the shade treatments. Leaves of the plants receiving 73% or 38% sunlight transmission exhibited a maximum leaf-to-air temperature difference of about 4^0C for plants that were allowed natural leaflet paraheliotropic movements (Fig. 3, left). In contrast, the treated plants exhibited maximum leaf-to-air temperature differences of 8°C for 73% light transmission and 6^0C for 38% light transmission

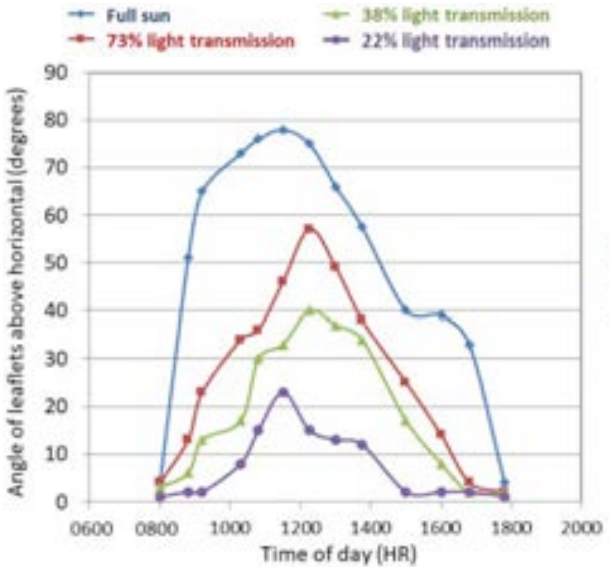


Figure 1. The diurnal cycle of *Serianthes nelsonii* leaflet movement on 10 February 2015 as influenced by percent sunlight transmission through shade treatments. N = 8.

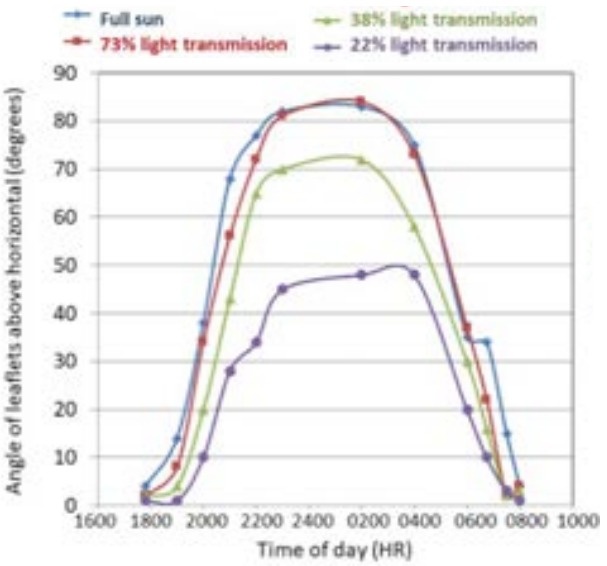


Figure 2. The nocturnal cycle of *Serianthes nelsonii* leaflet movement during the night following a clear day (10–11 February 2015) as influenced by percent sunlight transmission through shade treatments. N = 8.

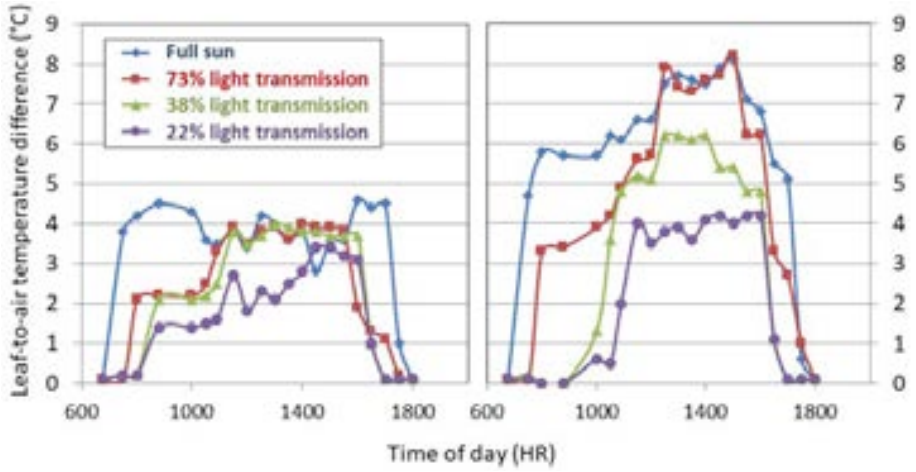


Figure 3. The diurnal cycle of *Serianthes nelsonii* leaf-to-air temperature difference as influenced by percent sunlight transmission through shade treatments on 10 February 2015. Leaflets were allowed to move to naturally avoid the solar beam (Left) Leaflets were not allowed to move to naturally avoid the solar beam (right). N = 4.

(Fig. 3, right). The plants receiving 22% light transmission exhibited the least differences between the treated and control plants, with a leaf-to-air temperature difference of about 3.4^{0}C for the control plants (Fig. 3, left) and about 4^{0}C for the treated plants (Fig. 3, right).

The direct temperature data provided a means of estimating the level of protection against high temperature stress afforded by *S. nelsonii* leaflet movement. Negating the benefits of leaflet movement generated leaf temperatures that were 8°C above ambient for the plants receiving the least protection by shade (Fig. 3, right). But allowing the natural paraheliotropic movements to avoid incident light provided 44–50 % improvement of leaf temperature for the full sun and 73% sunlight transmission treatments (Fig. 3, left). The leaf temperature improvement generated by leaflet movement of the plants receiving 22% sunlight transmission was much less, approximating 15% improvement of leaf temperature provided by leaflet movements.

Moving the orientation of plants throughout the photoperiod exerted a strong influence on ϕPSIIR.

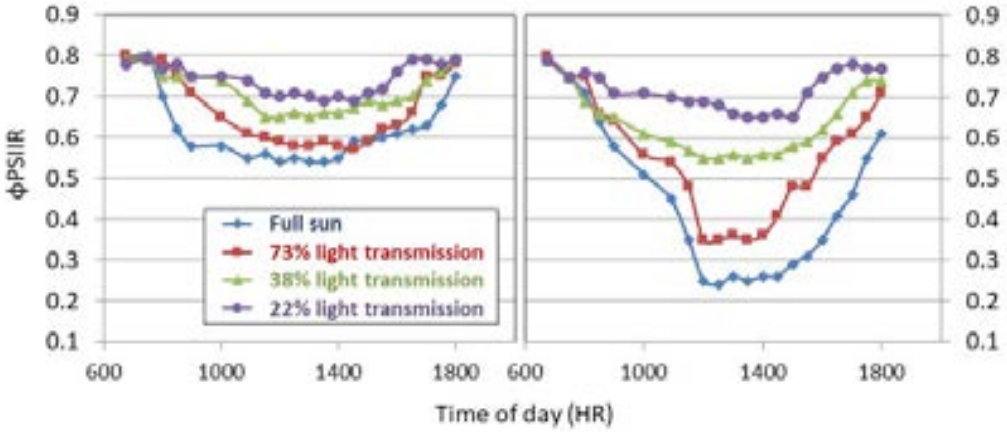


Figure 4. The diurnal cycle of quantum efficiency of Photosystem II for *Serianthes nelsonii* leaflets (ϕPSIIR) as influenced by percent sunlight transmission through shade treatments on 10 February 2015. Leaflets were allowed to move to naturally avoid the solar beam (left). Leaflets were not allowed to move to naturally avoid the solar beam (right). N = 4.

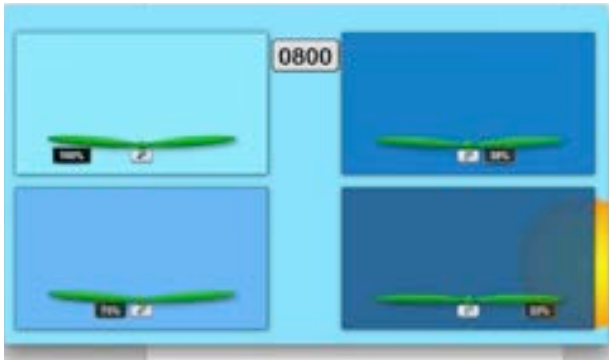
All four light treatments began the photoperiod with ϕPSIIR of 0.78 to 0.8. When plants were allowed to use leaflet paraheliotropism to avoid high light, the ϕPSIIR of leaflets of full sun plants declined to about 0.54 during midday (Fig. 4, left). In contrast, the full sun plants for which paraheliotropism was negated exhibited midday ϕPSIIR of about 0.24 (Fig. 4, right). The shape of the diurnal curves of ϕPSIIR were similar for all of the shade treatments. Midday ϕPSIIR for 73% light transmission plants was about 0.57 for control plants and 0.35 for treated plants. Midday ϕPSIIR for 38% light transmission plants was about 0.65 for control plants and 0.55 for treated plants. Middy ϕPSIIR for 22% light transmission plants was about 0.68 for control plants and 0.65 for treated plants. The ϕPSIIR of shaded plants that were allowed to exhibit paraheliotropism returned to the 0.78 or above by the end of the photoperiod (Fig. 4, left). In contrast, the ϕPSIIR of full sun plants recovered to 0.75 by the end of the photoperiod. For the treated plants which were denied the benefits of paraheliotropism, only the 22% light transmission plants were able to return ϕPSIIR to 0.78 or above by the end of the photoperiod (Fig. 4, right). This late afternoon recovery of ϕPSIIR was only 0.6 for the treated full sun plants.

DISCUSSION

My results indicated *S. nelsonii* plants are highly proficient at use of extreme control over leaflet movements as a strategy to regulate incident light load and protect the leaflets from high light damage when needed. The leaflet paraheliotropism enabled by pulvini afforded benefits for minimizing leaf-to-air temperature differences and improving quantum efficiency of Photosystem II. The daily ambient light load defined the extent of paraheliotropic movement of *S. nelsonii* leaflets and the level of protection that was provided by movement. Plants receiving high light load moved their leaflets early in the morning and reached leaflet angles near vertical for much of the photoperiod. In contrast, plants in deepest shade moved their leaflets very little throughout the photoperiod because they were not experiencing conditions in which they needed to avoid high light stress.

The ϕPSIIR data (Fig. 4) provided a means of estimating the level of protection against photoinhibition afforded by *S. nelsonii* leaflet movement. This fluorescence metric is useful for understanding the relative amount of absorbed light that is actually used in Photosystem II photochemistry (Genty et al. 1992; Murchie & Lawson 2013). The minimum ϕPSIIR for the full sun plants that were allowed paraheliotropic leaflet movements was 120% greater than the minimum ϕPSIIR for plants that were disallowed the protection of paraheliotropic movements. The level of protection afforded by paraheliotropism was moderated by the provision of shade. This was borne out by delaying the initial diurnal declines of ϕPSIIR in the morning and moderating the midday minimum of ϕPSIIR that was reached. For example, the level of midday protection for the plants receiving 22% sunlight transmission and allowed leaflet movement was only 8% greater than that of the plants that were disallowed the benefits of paraheliotropism. These benefits of leaflet movement were expected, as Photosystem II is particularly sensitive to thermal damage (Berry & Bjorkman 1980).

Diurnal control over leaflet angle also improves



Video 1. Animation of diel cycle of *Serienthes nelsonii* leaflet movements as influenced by four shade levels.

total canopy radiation interception and radiation-use efficiency on a daily basis because the leaflet angles of exterior leaves provide instantaneous control over sunlight penetration into the interior leaves of the canopy. Therefore, the use of tight instantaneous control over heliotropism confers a working photoprotective strategy and improves a tree's capacity to cope with daily environment variations. On cloudy days the outer leaflets may employ a diaheliotropic behavior whereby the lamina may be maintained perpendicular to the solar vector (Ehleringer & Forseth 1980). On those cloudy days the maximum use of the limited light by peripheral leaves may reduce photosynthesis of leaflets located inside the canopy by the process of mutual shading. On sunny days the outer leaflets may avoid the solar vector for most of the day by use of paraheliotropism, thereby increasing photosynthesis of leaflets located inside the canopy by allowing more sunlight to penetrate. The continuum between diaheliotropism and paraheliotropism has been reported for other species with pulvini-mediated leaf movements (Forseth 1990). This level of control over angle of the photosynthetic surface has been shown to profoundly benefit photosynthesis, carbon gain, and seed yield (Mooney & Ehleringer 1978; Forseth & Ehleringer 1983; dos Santos et el. 2006; Nilsen & Forseth 2018).

The reasons that leaflets of some species close at night are not fully understood, and the triggers that mediate nocturnal leaflet closure are not fully known. This nocturnal leaf movement is among the plant behaviors that follow circadian rhythms (Ueda & Nakamura 2007), and these circadian behaviors that can be anticipated by plants are advantageous to plant fitness (Dodd et al. 2005). *Serianthes nelsonii* plants in all four light treatments began to close after sunset, a process called nyctinasty. The ultimate magnitude of closure during the night was defined by the amplitude of closure that plants in each incident light treatment exhibited during the daytime. For example, leaflets of plants in the 22% sunlight transmission treatment never fully closed during the photoperiod because the shaded conditions mitigated high light stress and the need for protection from photoinhibition by leaflet movement was not severe. These same shaded plants exhibited an inability to fully close their leaflets at night and reached a maximum of only 50° above the horizontal. In contrast, the plants that received the high light treatments during the photoperiod exhibited an ability to fully close their leaflets at night, reaching a maximum of almost vertical. This nocturnal behavior may be under the control of learned behavior (Eisenstein et al. 2001), where the amplitude of tropic diurnal leaflet movement is perceived as a habitual behavior that controls the amplitude of nastic nocturnal leaflet movement. *Mimosa pudica* leaves have demonstrated similar learned behaviors of leaflet folding skills in response to doses of physical stimuli (Gagliano et al. 2014).

The timing of nocturnal leaflet closure and re-opening was generally synchronized among leaves of all four shade treatments even though the amplitude of closure was dissimilar. The re-opening of leaflets near the end of the nocturnal cycle began about 04.00h for all four treatments. By the time of sunrise, the leaflets were essentially fully open. The trigger for that synchronized *S. nelsonii* leaflet re-opening that begins several hours before sunrise is not known. Suggestions for what controls the timing of nocturnal leaflet movements include a circadian clock (Gorton & Satter 1983) or the lunisolar gravitational force (Barlow 2015). More research is needed to develop a greater understanding of the controlling mechanisms of the nyctinastic *S. nelsonii* leaf behaviors.

Conservation practitioners and planners need hard evidence to guide decisions. The recently described sub-discipline of conservation physiology (Wikelski & Cooke 2006) adds to the biodiversity conservation agenda by employing empirical approaches to determine cause-and-effect relationships of organisms and their environment (Cooke et al. 2013). For example, the detrimental effects of climate change on biodiversity conservation may be more fully understood by employing conservation physiology approaches (van Kleunen 2014). Ambient air temperature is highly influential in how legume leaflet movements benefit leaf function in high light conditions (Fu & Ehleringer 1989; Kao & Forseth 1992). My results indicate that threatened species such as *S. nelsonii* that are equipped with the ability to rapidly adjust the angle

of the photosynthetic organ to the solar vector may be better able to adjust to warmer global temperatures in the future, as they may be able to maintain the leaf-to-air temperature differences to a minimum while responding to increased ambient temperatures.

In summary, the Recovery Plan for *Serianthes nelsonii* (USFWS 1994) stated the need to conduct more research is a critical component of recovering this important tree species. Toward that end, I have shown that the tight control of diurnal leaflet movements enabled by pulvini at the base of *S. nelsonii* leaflets provided benefits by reducing heat gain due to maintenance of a beneficial angle in relation to the solar vector. The reduction in high light stress also reduced photoinhibition as characterized by an increase in the quantum efficiency of Photosystem II for plants that were allowed to exhibit para-heliotropic leaflet movements. Finally, the nocturnal nastic leaflet movements were correlated with the diurnal light exposure and corresponding paraheliotropic movements, with plants exhibiting the greatest extent of diurnal movements also exhibiting the greatest extent of nocturnal movements.

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COMMUNICATION

Pollination ecology of *Brownlowia tersa* (Malvaceae), a Near Threatened non-viviparous true mangrove shrub

Aluri Jacob Solomon Raju

Department of Environmental Sciences, Andhra University, Visakhapatnam, Andhra Pradesh 530003, India.
solomonraju@gmail.com

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Abstract: *Brownlowia tersa* is a low-ground semi-evergreen shrub species. The phenological events occur sequentially—leaf fall, leaf flushing, flowering and fruiting from April to November. It is hermaphroditic, protandrous, self-compatible, facultative xenogamous, and melittophilous involving worker honey bees, small male and female carpenter bees and male and female cuckoo bees. Of these, worker honey bees and female carpenter bees forage for both pollen and nectar while male carpenter bees and both sexes of cuckoo bees forage exclusively for nectar. Cuckoo bees are very important for cross-pollination because they are swift fliers and visit many flowers from different plants in the shortest time. Carpenter bees and honey bees are largely important for self-pollination as they are not fast fliers and tend to spend more time at each flower for forage collection. The flowers have a specialized pollination mechanism to resort to autonomous autogamy if not pollinated but this mode of pollination is subject to the availability of pollen in its own anthers. Fruit is a 1-seeded follicle produced from a single carpel of the flower. It is indehiscent and floats in tidal water when detached from the plant. When settled in muddy substratum, it breaks open to expose the seed which germinates and produces a new plant in quick succession. The study reports that the plant is highly threatened due to different human economic activities taking place in the area and hence immediate in situ conservation measures are required for its protection and propagation.

Keywords: Facultative xenogamy, hermaphroditism, melittophily.

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Society for Conservation Biology

INTRODUCTION

The Malvaceae family contains herbs and shrubs (Tang et al. 2007). Flowers of this family are usually hermaphroditic and entomophilous (Ruan 2010). Wind pollination in the species of this family is unlikely because the pollen grains are sticky and tend to clump together. Pollinators are mostly bees and butterflies; however, other pollinators are species-specific and include hawk moths, hummingbirds, and other birds (Rathcke 2000; Ruan 2010). In this family, the sub-family Brownlowioideae consists of eight genera with 70 species distributed in palaeo-tropical latitudes. This sub-family is characterized by sepals fused into a campanulate tube (Burret 1926), many stamens either unfused or slightly fused into fascicles at their base with or without staminodia (Ridley 1922; Hutchinson 1967), and ovaries sessile or borne on a short-stalk representing gynophore. Among these genera, *Brownlowia* consists of about 30 species widely distributed in southeastern Asia through Malaysia and the Pacific Islands (Tomlinson 1986). Different authors reported that *Brownlowia* is a genus of trees, comprising about 25 species in southern and southeastern Asia with Borneo as centre of its distribution where it is represented by 17 species of which 15 are endemics. Many species of this genus grow along rivers, in swamp forests and mangroves (Kostermans 1965; Turner 1995; Bayer & Kubitzki 2003). This genus is distinguished from other genera by its apocarpous fruits and loosely connected carpels (Bayer & Kubitzki 2003). Only two shrub hermaphroditic species *B. argentata* and *B. tersa* have been reported as occurring in swamp forests and river banks, and mangroves inundated by the highest tides (Tomlinson 1986). These two species have been classified as true mangrove species by different authors (Duke 1992; Giesen et al. 2007; Polidoro et al. 2010). *B. tersa* is distributed from India to southeastern Asia where it has been recorded in Myanmar, Cambodia, Thailand, Malaysia, Brunei, Singapore, the Philippines, Indonesia (Giesen et al. 2007). In India, its distribution is restricted to the east coast where it is common in West Bengal and Odisha but rare in the Godavari estuary of Andhra Pradesh, and the Andaman & Nicobar Islands (Venu et al. 2006; Kathiresan 2010; Bhatt et al. 2011). This species is distinguishable in the field based on certain characters such as the presence of brown-scaly twigs, lanceolate leaves with dull silvery undersurface and pear-shaped, 2-valved fruits. It often grows in stands along the banks, remains almost half-submerged during high tide, and withstands the tidal surges due to its intricate root system. Globally, it is reported as a true mangrove species (Duke 1992; Giesen et al. 2007; Polidoro et al. 2010) though it has not been included in the Indian mangrove flora in certain national and international status reports (Kathiresan & Bingham 2001; Kathiresan & Rajendran 2005; Anonymous 2008; Mandal & Naskar 2008). But, it is reported as a true mangrove species in the mangrove flora of Andaman & Nicobar Islands (Sahni 1958; Debnath 2004). In the IUCN Red List, it is included in the Near Threatened category (Kathiresan 2010; Polidoro et al. 2010) and the reasons stated for this status include habitat loss from coastal development, erosion and the construction of shrimp and fish ponds throughout its range. Further, it is also stated that this species may qualify for threatened category in the near future due to its occurrence only on the landward margin where it is the most vulnerable to coastal development and human activities (Kathiresan 2010). *B. tersa* has been in use as a traditional folk remedy for diarrhoea, dysentery, wounds and boils. Roots possess antibacterial activity while leaves possess anti-inflammatory, antioxidant, analgesic and anti-diarrhoeal activities (Hossain et al. 2013). Despite its threatened status, there have been no studies on the reproductive biology of this species in any part of its distribution. Further, the other species *B. argentata* has also not been investigated for its reproductive biology so far. Tomlinson (1986) noted that the pollination biology of *Brownlowia* is unknown. Since then, no one has ever attempted to report on the pollination biology of any species of this genus.

The study is aimed at providing certain details of floral biology and pollination in *B. tersa* which is currently in threatened status at Coringa Mangrove Forest (CMF), Andhra Pradesh, India. This information is useful to understand the sexual, breeding, and pollination systems and fruiting ecology. Further, it provides clues to understand why it attained threatened status not only at this forest and also at other mangrove forests where it is distributed.

MATERIALS AND METHODS

CMF covering an area of 188km^2 lies at 16^{0}43’47.413”N and 82^{0}12’54.864”E. It is located in the delta in East Godavari District; it is created by the river Godavari. Freshwater flows into the mangrove wetlands of the Godavari delta for a period of six months and peak flow normally occurs during July to September, coinciding with the southwest monsoon season. During this period the entire delta, including the mangrove wetland is

submerged under freshwater, since penetration of sea water is completely blocked by the large amount of incoming freshwater. Brackish water conditions prevail from October to February and sea water dominates the entire mangrove wetland from March to May due to the absence of freshwater discharge. In recent times, however, freshwater discharge from the river system is low due to insufficient and erratic rainfall during monsoon seasons.

Field studies were carried on the populations of *Brownlowia te*rsa (L.) Kosterm. in the areas of Ratikalva Reserve Forest which falls under non-sanctuary area of CMF. Observations regarding the organization of inflorescences, the spatial positioning of flowers, and their position on the plant were made since these features are regarded as important for foraging and effecting pollination by flower-visitors. The flower longevity was recorded by marking 20 just open flowers and following them until fall off. Anthesis was initially recorded by observing 10 marked mature buds in the field. Later, the observations were repeated five times on different days, each day observing 10 marked mature buds in order to provide accurate anthesis schedule. The same marked mature buds were followed for recording the time of anther dehiscence. The presentation pattern of pollen was also investigated by recording how anthers dehisced and confirmed by observing the anthers under a 10x hand lens. The details of flower morphology such as flower sex, shape, size, colour, odour, sepals, petals, stamens and ovary were described.

Twenty-five mature but un-dehisced anthers were collected from five randomly chosen plants and placed in a petri dish. Later, each time a single anther was taken out and placed on a clean microscope slide (75 x 25 mm) and dabbed with a needle in a drop of lactophenol-aniline-blue. The anther tissue was then observed under the microscope for pollen, and if pollen grains were not there, the tissue was removed from the slide. The pollen mass was drawn into a band, and the total number of pollen grains was counted under a compound microscope (40x objective, 10x eye piece). This procedure was followed for counting the number of pollen grains in each anther collected. Based on these counts, the mean number of pollen produced per anther was determined. The characteristics of pollen grains were also recorded. The stigma receptivity was observed by H_2O_2 test as given in Dafni et al. (2005).

The presence of nectar was determined by observing 50 mature buds and open flowers collected at random from 10 plants. Individual volumes of nectar were recorded for 20 flowers and then the average volume of nectar per flower was determined and expressed in µl. The flowers used for this purpose were bagged at the mature bud stage, opened after anthesis and nectar squeezed into micropipettes to measure the volume of nectar. Nectar sugar concentration was also simultaneously determined using a hand sugar refractometer (Erma, Japan).

Fifty flowers each from 10 randomly selected plants were used for each mode of the breeding system. The stigmas were pollinated with the pollen of the same flower manually by using a brush; they were bagged for fruit set through manipulated autogamy. The flowers were fine-mesh bagged without hand pollination for fruit set through spontaneous autogamy. The emasculated flowers were hand-pollinated with the pollen of a different flower on the same plant; they were bagged and followed for fruit set through geitonogamy. The emasculated flowers were pollinated with the pollen of a different individual plant and bagged for fruit set through xenogamy. All these modes of pollination were followed for one month for calculating the percentage of fruit set in each mode. Twenty inflorescences consisting of 125 flowers were tagged on 20 plants prior to anthesis and followed for fruit set rate in open-pollinations. Fruit maturation period, fruit dehiscence, seed dispersal and establishment were observed in detail.

The insects visiting the flowers were bees only and they had their nesting sites close to *B. tersa* populations. They were observed carefully for 10 hours a day for 15 days in different weeks during the flowering season. The hourly foraging visits of each bee species were recorded on 10 different days for which 30 inflorescences were selected. The data obtained was used to calculate the percentage of foraging visits made by each bee species per day in order to understand the relative importance of each bee species. Simultaneously, the bees were observed for their foraging behavior such as mode of approach, landing, probing behaviour, the type of forage they collected, contact with essential organs to result in pollination, and inter-plant foraging activity. The bees were captured from the flowers during 10.00–12.00 h on five different days for pollen analysis in the laboratory. For each bee species, 10 specimens were captured and each specimen was washed first in ethyl alcohol and the contents stained with aniline-blue on a glass slide and observed under a microscope to count the number of pollen grains present. In the case of pollen collecting bees, pollen loads on their corbiculae/scopae were separated prior to washing them. From pollen counts, the average number of pollen grains carried by each bee species was calculated to know the pollen carryover efficiency of different bees.

RESULTS

Habit and phenology

Brownlowia tersa is a semi-evergreen bushy and spreading shrub distributed in sunny locations along tidal creeks and brackish water creeks where mud is accreting (Image 1a). A green snake (unidentified) uses the habitat of this plant in all locations where the plant occurs (Image 1b,c). It grows up to two meters in height without any above ground roots. It is fast growing, much-branched and forms pure stands. The branches are grey, smooth and marked with lines and grooves along their length. Leaves are petiolate, lanceolate to elliptic-lanceolate and leathery with a rounded base and a pointed tip; the upper surface is glossy and smooth while the lower surface is grey-green and covered with a dense layer of tiny, hairy scales. Leaf fall occurs during late April to late May, leaf flushing during June–July and flowering during late July to second week of September at population level. Individual plants flower for about four weeks only. Inflorescence is terminal and axillary; it is a paniculate cyme with several flowers which open over a period of about a week. (Image 1e,f). Cauliflorous flowers are also borne on main stems and woody trunks.

Flower morphology

Flowers are pedicellate, 5–7 mm long, 5-6 mm wide, creamy-brown coloured, mildly odoriferous, bisexual and actinomorphic. Calyx is bell-shaped, 5-sepalled, connate below and light yellow with brown dots all over. Corolla is cream-coloured with light yellow base, 2–3 mm longer than calyx, 5-petalled, free and apex rounded. Stamens are many, free, present in five bundles and free from calyx and corolla. Anthers are petaloid and attached to the filament by the base. Ovary sits on a well-developed stalk. It has four carpels which are partially joined and each carpel has two reniform ovules (Image 2k–n). All four carpels are joined by a common style tipped with a simple stigma.

Floral biology

Mature buds are globose and open during 09.00–11.00 h with peak opening at 10.00h (Image 2a–g). The stamens show anther dehiscence by longitudinal slits during anthesis. In mature buds, the stigma is below the height of stamens but stands straight and erect beyond the height of the anthers during anthesis. The stigma remains so for 6 hours and gradually curves towards the anthers of the same flower and eventually contacts its own pollen. It attains receptivity three hours after anthesis and remains so for five hours. The pollen grains are oblate-spheroidal, yellow, 3-colporate, sexine thinner than nexine and 27–29 µm in size (Image 2h–j). They are initially sticky but later turn powdery with a gradual increase in temperature and fall as single grains. Individual anthers produce 890.6 ± 52.83 pollen grains and the total pollen output by a flower depends on the number of stamens produced. The stigma terminates

Image 1. *Brownlowia tersa*: a - Habitat | b&c - Habitat for Green Snake | d - *Thyreus histrio* resting on the stem | e - Twig with early stage of inflorescence | f - Inflorescence with maturing buds. © A.J. Solomon Raju.

its receptivity by the end of the day. Nectar is produced in minute volumes around the base of the carpels and is protected by the basally connate calyx; it amounted 1.2 ± 0.23 µl per flower and the sugar concentration stood at 28 ± 1.5%. The flowers fall off by noon of the second day.

Breeding systems

Hand-pollination tests showed that the plant produces fruit through self and cross-pollination. Fruit set rate varied from 14–34 % in unmanipulated and manipulated autogamy, 50% in geitonogamy, 72% in xenogamy and 34% in open-pollination. These results indicate that fruit set is the highest in xenogamy and lowest in unmanipulated autogamy among hand-pollination tests. Fruit set evidenced in open-pollination is taken as the product of auto-, geitono- and xeno-gamy (Table 1).

Table 1. Results of breeding systems in *Brownlowia tersa*.

Pollination mode	No. of flowers pollinated	No. of fruits formed	Fruit set (%)
Autogamy (unmanipulated)	50	7	14
Autogamy (manipulated)	50	17	34
Geitonogamy	50	25	50
Xenogamy	50	36	72
Open-pollination	125	43	34

Flower visitors and pollination

The flowers were foraged exclusively by bees during 09.00–17.00 h with peak activity during 10.00–13.00 h coinciding well with the availability of more fresh flowers (Fig. 1). The bees belong to Apidae family and included honey bees (*Apis cerana* F. and *A. florea* F.), a small carpenter bee (*Ceratina binghami* Cockerell) and a cuckoo bee (*Thyreus histrio* F.; Image 1d). In honey bees, only worker bees visited the flowers and foraged for both pollen and nectar. Worker bees collected pollen, groomed and brushed it down towards the hind legs and packed the pollen into the corbiculae or pollen baskets which are located on the tibia of the same legs. They used nectar collected by them for their own consumption and also for feeding the queen and male bees of the hive nearby in the same forest. In other bee species, both male and female bees visited the flowers. The male carpenter bee foraged for only nectar while female bee foraged for both pollen and nectar. The male carpenter bee collected nectar for its own consumption while female carpenter bee used the nectar collected by it for its own consumption and also mixed it with pollen to make bee bread to feed the larvae. The female carpenter bee collected pollen and packed it as honey bees did but they packed it into the weak scopa surrounded by sparse body hairs located on the tibia of hind legs. The male and female cuckoo bees foraged for only nectar for their own consumption. The floral architecture facilitated the bees to probe for the forage with great ease and during probing they contacted the stigma and stamens effecting pollination. Worker honey bees and the female carpenter bees tended to spend more time at each flower, plant and patch as they were involved in collecting both pollen and nectar while male carpenter bees and both sexes of cuckoo bee tended to spend less time at each flower, plant and patch as they were involved in collecting only nectar. All four bee species made inter-plant and inter-patch flower visits in

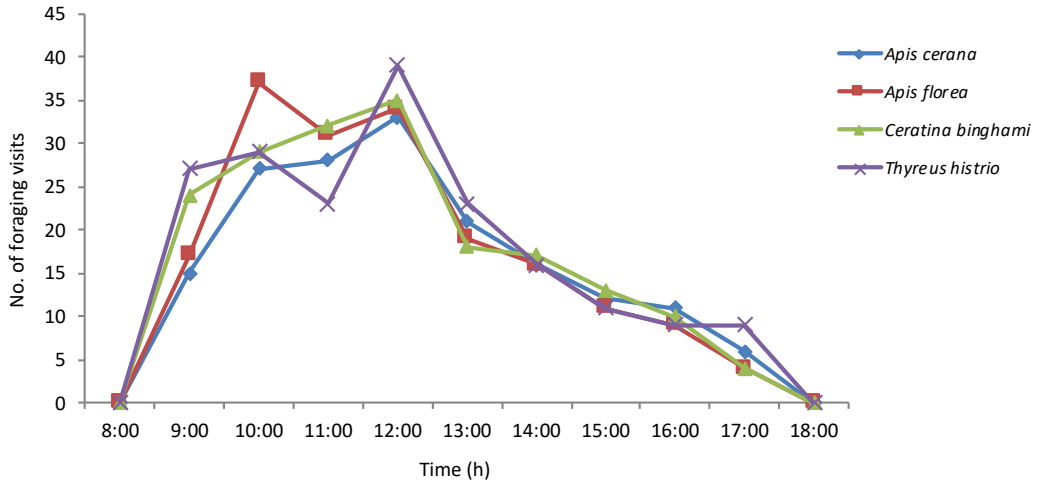

Figure 1. Hourly foraging activity of bees on *Brownlowia tersa*.

Image 2. ***Brownlowia tersa:*** **a–g - Different stages of anthesis | h - Dehisced anthers with yellow powdery pollen | i&j - Pollen grains | k&l - Ovary, style and stigma | m - Simple stigma | n - Ovules | o - Fruiting | p - Cauliflorous fruits | q - Seed germination | r - Seedling | s - New plant. © A.J. Solomon Raju.**

Table 2. Pollen recorded in the body washings of insect foragers on *Brownlowia tersa.*

Insect species	Sample size (N)	Range	Mean	S.D.
Apis cerana	10	54–208	115.4	50.08
Apis florea	10	93–156	99.1	19.44
Ceratina smaragdina	10	95–129	98.1	12.23
Thyreus histrio	10	67–304	162.3	75.49

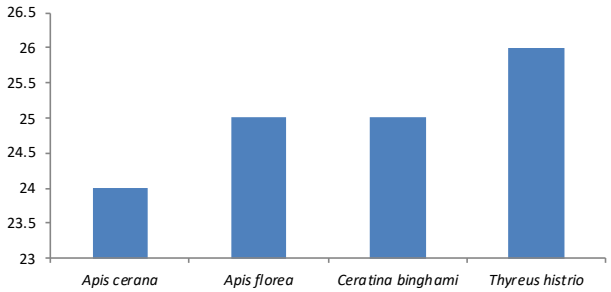

Figure 2. Relative percentage of foraging visits of bees on *Brownlowia tersa.*

quest of more forage and in the process they effected both self- and cross-pollinations. Among all four bee species, *T. histrio* made 26%, *A. florea* and *C. binghami*, each 25% and *A. cerana* 24% of total visits recorded at the flowering patch (Fig. 2). The pollen recorded in body washings of sampled specimens of bees indicated that all of them carry and transfer pollen to other flowers either in the same or different patches. The average number of pollen grains recorded was 115.4 for *A. cerana*, 99.1 for *A. florea*, 98.1 for *C. binghami* and 162.3 for *T. histrio* (Table 2).

Fruiting ecology and seed dispersal

In fertilized flowers, calyx remains for about a week without any further development and falls off subsequently. A single carpel produces fruit in fertilized flowers. Fruits mature in about four weeks; remain greyish-green from fruit initiation and until dispersed (Image 2o,p). Individual fruit is a woody, fibrous heart-shaped follicle, 12–15 mm long and bi-lobed with a single seed. It is indehiscent while on the plant, falls off when due, floats due to its fibrous husk of fruit carpel, imbibition of water by it; this floating state of fruits

facilitated their dispersal by tidal water. When it settles on the muddy substratum and upon imbibition, it breaks open exposing the seed but fruit carpel remains intact until seed germination. With initiation of root growth and development, the cotyledons shed the fruit carpel and show continued growth to form seedlings and subsequently new plants (Image 2q–s).

DISCUSSION

Brownlowia tersa is a shrubby, spreading plant and forms patchy distribution along the tidal creeks connecting the landward zone at the study area. An unidentified green snake has been found to use this gregarious shrub at all locations of its occurrence for its shelter but why it uses the habitat of this particular plant is unknown. In *B. tersa*, flowering and fruiting seasons are variously reported by different authors. Kathiresan (2010) noted that it flowers and fruits during July–October but he has not mentioned the location where it was recorded. Ragavan et al. (2016) noted that it flowers during February–March and fruits during April–July in India and Andaman & Nicobar Islands. The present study made at CMF India showed that all phenological events occur sequentially—leaf fall, leaf flushing, flowering, and fruiting—from April to November. Flowering starts in late July and continues for about seven weeks while fruiting during October–November at population level, however, individual plants flower for less than a month. The flowers are borne in terminal and axillary paniculate cymes as well as on main stems and woody trunks indicating that the plant with shrubby habit perhaps evolved to compensate the brief period of flowering by producing cauliflorous flowers in order to attract pollinators and maximize fruit set at plant level.

Different authors provided taxonomic characters of *B. tersa* but certain characters have been incorrectly reported. Judd & Manchester (1997) reported that *Brownlowia* flowers have five elongate antipetalous staminodia while Chung & Soepadmo (2017) noted that *B. tersa* flowers have lanceolate staminodes and persistent androgynophore. The present study showed that *B. tersa* lacks staminodia and androgynophore but it has gynophore on which the ovary is well seated. Further, the stamens are bundled, anthers petaloid which dehisce by longitudinal slits, and the carpels with reniform ovules are partially joined by a common style terminated with a simple stigma. The floral details of *B. tersa* clearly indicate that the plant is morphologically and functionally hermaphroditic. Protandry and the erect position of the stigma above the anthers facilitate the occurrence of only geitonogamy and xenogamy for a brief period; in addition, vector-mediated autogamy also occurs upon the commencement of stigma receptivity. Finally, the flowers resort to autonomous autogamy by gradually curving the style and stigma towards the anthers; this pollination mode is a "fail-safe" strategy evolved by the plant to ensure pollination in flowers that have not been pollinated by pollinator bees. Its occurrence, however, is subject to the availability of pollen in the anthers of the same flower. Ruan et al. (2010) reported on style curvature and its role in effecting self-pollination in 52 species of Malvaceae. These authors classified the studied species into two types: species with style curvature before pollen shedding, and species with style curvature after pollen shedding. In the former type, the styles remain erect if stigmas are pollinated or cease to curve if pollination occurs in the process of style curvature or continue to curve downwards towards the anthers if not pollinated. In the latter type, the styles curve eventually bringing stigmas down to establish contact with the anthers. The style curvature and eventual occurrence of self-pollination in *B. tersa* represents the second type, sensu Ruan et al. (2010). Therefore, *B. tersa* is a perfect hermaphroditic species with facultative xenogamous mating system.

Ruan (2010) stated that anemophily is unlikely in Malvaceae because the pollen grains are sticky. Spira (1989) reported that *H. moscheutos* with sticky pollen grains is not anemophilous and a vector other than wind is needed for successful pollination. The present study shows that *B. tersa* pollen is also sticky and in effect, the bees foraging on the flowers collect pollen slowly indicating that the plant is not anemophilous. Further, the sticky nature of the pollen enables the plant to avoid anemophily during non-receptive phase of the stigma to maximize cross-pollination and minimize self-pollination. Feng (1984) and Rachcke (2000) reported that many species of Malvaceae are entomophilous and pollinated by bees, butterflies, hawk moths and birds. Faegri & van der Pijl (1979) and Proctor et al. (1996) reported that bee-pollinated flowers vary in their size, shape and colouration; they may be open and bowl-shaped (radially symmetrical) or more complex and non-radially symmetric (zygomorphic), and offer nectar and pollen as rewards. The present study reports that *B. tersa* displays a radially symmetrial flower shape, dull-coloured corolla, mildly odoriferous and also offers nectar and pollen as rewards to pollinators; in line with this, the plant is pollinated exclusively by bees and hence it is melittophilous. Among bees, *Apis* spp. carry

pollen in pollen baskets located on their hind legs for use subsequently by their colony while female bees of *C. binghami* carry pollen in the scopae located on their hind legs for brood provisioning. The pollen collection activity by these bees significantly decreases pollen availability for pollination purpose although pollination is effected by them, and also it mostly undermines the occurrence of autonomous autogamy towards the end of the day. The production of many flowers in paniculate cymes, on main stem and woody trunk daily, individual flowers with several stamens and each stamen producing copious pollen appear to enable the plant to compensate the pollen loss caused by *Apis* and *C. binghami* bees, however. Male bees of *C. binghami* and both sexes of *T. histrio* act exclusively as nectar feeders and play principal role in the pollination of *B. tersa*. Further, *T. histrio* is a swift flier, collects nectar from as many flowers as it could in a single visit and hence is very important in effecting cross-pollination. *Apis* bees build their colonies on the peripheral branches of *Excoecaria agallocha* while *C. binghami* has its nests in the stems of *Acanthus ilicifolius*; these plant species occur 5–10 m away from *B. tersa*. *T. histrio* does not have its own nest but it uses the underground nests of *Amegilla* sp. which occur nearby on the landward side of the mangrove forests. Since the nests of all these bee species occur near *B. tersa*, they display a situation of floral constancy and effect pollination due to massive flower production by the plant during the flowering season.

In the present study, hand-pollination tests on *B. tersa* indicated that the plant is self-compatible and fruits through all modes of pollination with varying levels of reproductive success, however, fruit set rate in open-pollinations is not commensurate compared with the ability of the plant to fruit through autogamy with or without involvement of pollinators and through geitonogamy and xenogamy with the involvement of pollinators. Further, the flowers characteristically produce 1-seeded fruits only from a single carpel indicating that only one out of four carpels forms fruit and only one of 2-ovules of the carpel forms seeds. The fruits are indehiscent and float in tidal water upon detachment from the plant. Different authors noted that *Brownlowia* species are often dispersed by water indicating that they float in tidal water (Kostermans 1965; Turner 1995; Bayer & Kubitzki 2003). Similarly, Rachmadiyanto et al. (2017) reported that *B. peltata* also produces 1-seeded fruits from a single carpel but the fruits dehisce into carpels to expose the seeds; the fruits float and disperse by water. The fruits of *B. tersa* float because fruit pericarp is fibrous and imbibe water. Since the locations of the plant are situated towards landward zone, the fallen fruits do not disperse longer distances and soon they settle in muddy substratum. Gradually, the seed inside the fruit imbibes water and breaks the fruit open exposing the seed which soon germinates and produces a seedling and then a new plant. The fruit pericarp, however, remains enclosing the cotyledons until the initiation of root formation by the seedling. Similar process of fruit floating and seed germination is reported in *B. peltata* by Rachmadiyanto et al. (2017).

Gopal & Chauhan (2006) noted that *B. tersa* populations are experiencing severe loss at the range margins due to human activities and coastal development and hence has become an endangered species in India while Kathiresan (2010) mentioned that *B. tersa* is Near Threatened. Field studies conducted in this mangrove forest area for the last 12 years for the reproductive ecology information on different mangrove plant species showed a gradual decrease in the population size of *B. tersa* due to deforestation and modification for fuel wood collection, cattle shelter and eco-tourism activities. This situation is to be corrected otherwise this species would face the risk of genetic erosion and become extirpated in the course of time. Therefore, immediate and effective in situ conservation measures are necessary for its protection and propagation.

CONCLUSIONS

Brownlowia tersa is a low-ground semi-evergreen shrubby species. It displays phenological events sequentially—leaf fall, leaf flushing, flowering, and fruiting—from April–November. It is hermaphroditic, protandrous, self-compatible, facultative xenogamous and melittophilous. It has the ability to fruit with or without pollinator activity but fruit set rate is the highest with pollinator activity. Pollinators are exclusively bees consisting of honey bees, small carpenter bees, and cuckoo bees of which the last one is very important for cross-pollination due to their swift flying behavior and ability to collect nectar from many flowers of different plants. Fruit is a 1-seeded follicle and produced from a single carpel of the flower. It is indehiscent and floats in tidal water when detached from the plant. When settled in muddy substratum, it breaks open to expose the seed which germinates and produces a new plant. The study reports that the plant is highly threatened due to land use changes and regular human and cattle activity, and hence immediate in situ conservation measures are required for its protection and propagation.

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A note on the taxonomy and natural history of the Summer Clicker *Lahugada dohertyi* (Distant, 1891) (Insecta: Hemiptera: Cicadidae) along with its distribution in northern West Bengal, India

Vivek Sarkar

North Orissa University, Department of Zoology, Sri Ram Chandra Vihar, Takatpur, Mayurbhanj, Baripada, Odisha 757003, India.

UNESCO Category-2 Centre, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India.
viveksarkar87@gmail.com

Abstract: *Lahugada dohertyi* is one of the many lesser-known cicadas of northeastern India which has never been studied since its discovery. Recently, a century later, a population of this elusive cicada was discovered in northern West Bengal. This paper gives an account on its distribution in northern West Bengal, taxonomy, and natural history and suggests a common name based on its call and habitat preferences.

Keywords: Cicada, common name, Ochre Summer Clicker.

Bangla abstract: উত্তর পূর্ব ভারতের বহু স্বল্পপরিচিত ঘন্টি পোকার মধ্যে লাহুগাডা দোহের্তাই একটি এমন ঘন্টি পোকা যার আবিষ্কারের পর থেকে কোনো অধ্যায়ন হয়নি। সম্প্রতি, প্রায় এক শতক পরে, এই অধরা ঘন্টি পোকাটি উত্তর বঙ্গে পুনরাবিষ্কার হয়। এই প্রবন্ধ উত্তর বঙ্গে ইহার সংস্থান, বর্গিকরণ এবং প্রাকৃতিক ইতিহাসের উপর আলোকপাত করবে এবং ইহার শব্দ ও পছন্দের প্রাকৃতিক আবাসের উপর ভিত্তি করে ইহার সহজরণ ইংরেজি নামও উত্থাপন করবে.

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Author details: Vivek Sarkar is pursuing his PhD from North Orissa University on the cicadas of Garo, Khasi and Jaintia hills of Meghalaya State of India parallel to his job as World Heritage Assistant in UNESCO C2C at Wildlife Institute of India.

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INTRODUCTION

Lahugada dohertyi is a rusty red-coloured cicada that was described by William Lucas Distant in 1891 from a single male specimen (Image 1) collected by the American entomologist William Doherty from Margherita of Upper Assam (Fig. 1; Distant 1891, 1905). It was initially described as *Pomponia dohertyi* Distant, 1891 (Distant 1891; Sanborn 2014; Price et al. 2016) and later transferred to the monotypic genus *Lahugada* Distant, 1905. Unlike the members of *Pomponia* Stål, 1866, the opercula in the male of the species are short, somewhat globose, wider than abdominal margins, and distinctly visible from above (Distant 1906). For more than a century, nothing was known about its range, distribution, habitat preferences, or activity period. Recently, in 2014, I found the species in and around Coochbehar Town, situated in northern West Bengal State of India, which gave me an opportunity to observe and study this cicada closely. This newly found point location report was mentioned in the recently published annotated provisional catalogue of cicadas of the Oriental region (Price et al. 2016). The catalogue, however, does not give any account on its distribution, biology, or natural history. This paper gives a brief description of the taxonomy, larval morphology, and natural history of this lesser-known cicada along with a note on the distribution of this species in other parts of northern West Bengal.

MATERIAL AND METHODS

Specimen collection: Most of the cicadas in the field were spotted by their calls. Individual cicadas were observed through Canon EOS-600D Rebel T3i Digital SLR with Sigma 70–300 mm APO-Digimacro lens and the observed behaviour was noted down. Though an attempt was made to take the counts of the individuals, due to a lack of uniform and adequate sampling technique, it is not included in the paper. After collection, two legs and part of the thoracic tissues were extracted in order to preserve the DNA for future molecular work. Each insect was fixed with a pin through the mesonotum with wings outstretched after the extraction of the tissue. After fixing the insect, it was kept in a hot air oven for 48 hours at 56°C. The larval exuviae were collected from the habitat situated in the Coochbehar suburbs. This cicada emerges after dark and the adult often settles next to the exuviae till morning, till the body is dry and it develops colour. Only these exuviae, which were confirmed to be of *Lahugada dohertyi*, were collected for this study.

Imaging: Panasonic Lumix DMC FZ-35 and Canon EOS-600D Rebel T3i DSLR with Sigma 70–300 mm APO-Digimacro lens were used to photograph the cicadas in the field. Canon EOS-1200D DSLR with Canon 50mm macro lens was used to photograph the specimen in the collection depository of National Centre of Biological Sciences (NCBS). Labomed Luxeo 2SA microscope was used to take images and examine specimens for morpho-taxonomic work. Canon EOS-600D Rebel T3i DSLR with Canon 100mm macro lens and external flashes were used to photograph the larval exuviae.

Dissection: The last two abdominal segments of the male specimen (NCBS-PZ562) were treated using 10% KOH to dissect the genitalia, which was then preserved in 0.5ml vials containing anhydrous glycerol.

Morpho-taxonomy: The terminology used for the description of the adult cicada and the larval exuviae was adopted from Moulds (2005) and Hou et al. (2014), respectively.

Measurement: Morphometric measurements of the adult cicadas were taken from images using ImageJ (64-bit Java 1.6.0) software. The measurement of the larval exuviae is not produced in this paper as the exuviae tend to shrink while drying, right after the eclosion, distorting the actual measurement of the living last instar larvae.

Location: The species was first found opportunistically in Chakchaka, a suburb of Coochbehar, in May 2014. A few days later it was found in Rasamati Reserve Forest. An attempt was made to conduct more focused active searches for three weeks (22 April–13 May 2014) to check parts of Alipur, Jalpaiguri, and Coochbehar districts of northern West Bengal in order to understand the distribution pattern of this cicada. The same localities were again checked briefly in May 2015. In 2016, all the localities were monitored from April to May in order to record its activity period. All the localities of this cicada found in northern West Bengal are given in Table 1 and shown in Fig. 1. The GPS locations of its precise localities were acquired but only degree and minutes are produced in the paper due to conservation issues. This cicada was not found in the northern part of Alipur District towards Jayanti of Buxa Tiger Reserve, the northwestern part of Jalpaiguri District such as Baikunthapur Reserve Forest, Belacoba, Ambari, Odlabari, and Mal Bazar areas, and the southern part of Jalpaiguri and Coochbehar districts such as Haldibari, Ghugumari, Sitalkuchi, Jiranpur, Balarmpur, and Dinhta despite active search in the forested areas.

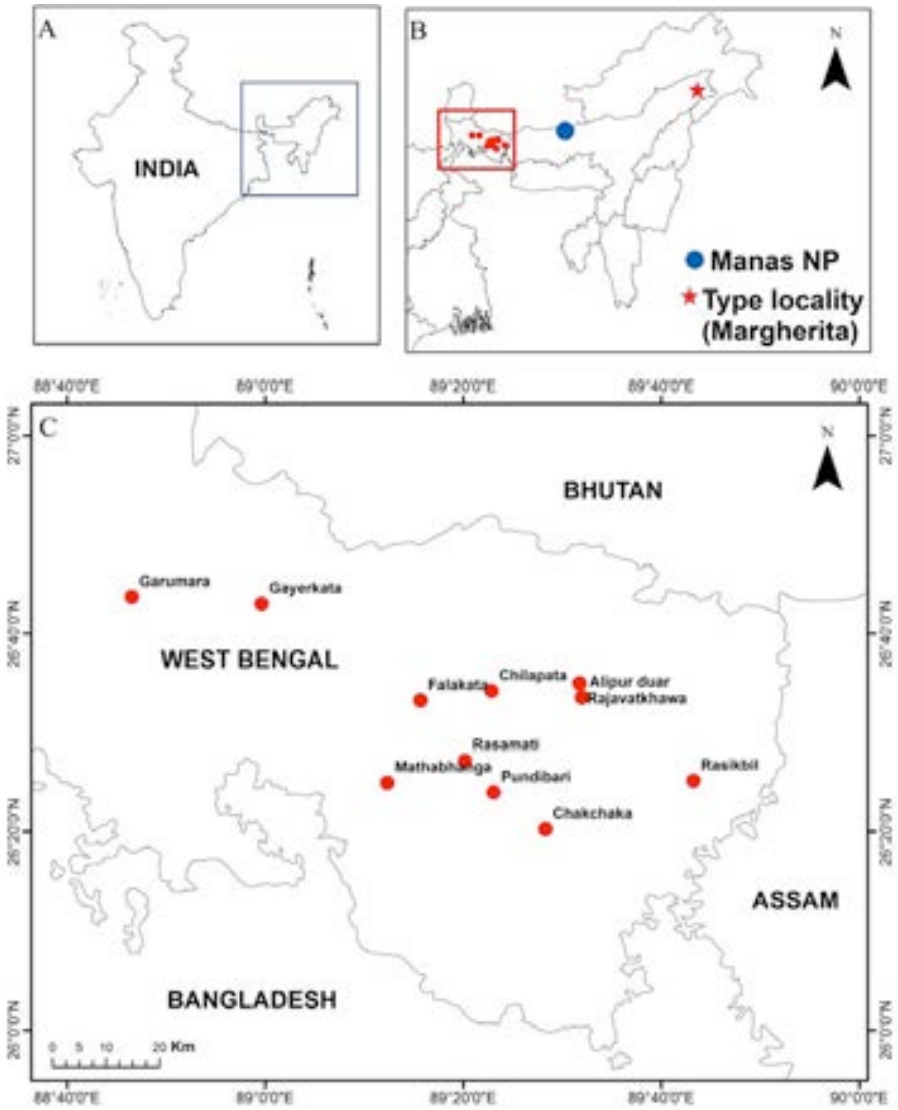

Figure 1. A—Northeastern India, including West Bengal | B—Localities where *Lahugada dohertyi* was recorded in northeastern India | C—Localities where *L. dohertyi* was recorded in northern West Bengal.

Table 1. Localities where *Lahugada dohertyi* was recorded in northern West Bengal, India.

	District	Locality	Latitude	Longitude
1	Coochbehar	Rasamati	26.450	89.333
2	Coochbehar	Pundibari	26.400	89.383
3	Coochbehar	Chakchaka	26.333	89.466
4	Coochbehar	Mathabhanga	26.400	89.200
5	Coochbehar	Rasikbil	26.416	89.716
6	Alipur	Rajavatkhawa	26.583	89.516
7	Alipur	Alipur duar	26.550	89.516
8	Jalpaiguri	Falakata	26.550	89.250
9	Jalpaiguri	Chilapata	26.566	89.366
10	Jalpaiguri	Garumara	26.716	88.766
11	Jalpaiguri	Gayerkata	26.716	88.983

RESULTS

A. Description of *Lahugada* Distant, 1905

Head (including eyes) considerably narrower than base of mesouotum, its length about equal to space between eyes, its lateral margins discontinuous, the lateral margins of front being almost at right angles to those of vertex; pronotum almost as long as mesonotum, narrowed anteriorly, the posterior angles prominent and rounded; metanotum strongly exposed behind the cruciform elevation; abdomen considerably longer than the space between apex of front and base of cruciform elevation; tympana completely covered, tympanal coverings broader than long and transversely rugulose; opercula short, somewhat globose, wider than

Image 1. *Lahugada dohertyi* (holotype, BMNH(E) 1009462): a—dorsal view | b—ventral view. © Trustees of the Natural History Museum, London. Photographed by BW Price and EL Allan.

abdominal margins, and distinctly visible from above; rostrum about reaching the posterior coxae; forewings and hindwings hyaline, the first with eight apical areas and the basal cell longer than broad (Distant 1906).

Diagnosis of *Lahugada dohertyi*

Head: Head (and pronotum, and mesonotum) dark ochraceous, head with the eyes fuscous, the area of the ocelli and lateral margins of vertex infuscated (Distant 1906). Head is rich ochraceous on the dorsal side along with greenish infuscation at the epicranium in the live specimen which turned darker in the preserved specimen. Ventral and frontal parts such as lorum and gena of the head is pale castaneous. Entire eyes are a rich brown, darker than the head in most of the individuals. In occasional cases, however, a few individuals have eyes that are pale coloured, similar to that of the dorsal part of the head but with fuscous pseudopupil in the centre (Image 2F). The entire postclypeus is rich ochraceous in colour. Postclypeus not concave and rather flat towards the front. Antenna ochraceous. Ocellus pale sanguine in live or newly preserved insect.

Thorax: Pronotum with a subobsolete central fascia, with a dark spot at base and apex, a short discal fuscous streak on each side, the incisures and outer margins also infuscated; mesonotum with two small central obconical spots, some subobsolete fasciae on each side, and with two small blackish spots in front of the cruciform elevation, the centre of which is dark fuscous; tegmiua and wings hyahne, with a slight bronzy tinge and unspotted, the venation dark ochraceous; body beneath and legs dark ochraceous; apex of rostrum and tarsal claws fuscous (Distant 1906). Thorax rich ochraceous. Pronotum have a dark rusty dorsal central infuscation from the back of the head till pronotal collar which tends to darken and form a spot-like appearance adjacent to pronotal collar but does not go inside the collar. Paramedian fissure darkens towards the inside and forms a dark greenish line-like infuscation beyond the fissure, tends to meet adjoining point of lateral fissure infuscation and pronotal collar. Greenish (in live insect) infuscation at lateral fissure straight and broadens towards the pronotal collar. Lateral part of pronotal collar uneven with darker lateral margin. All greenish infuscation turns dark or black in the dried specimen. Mesonotum ochraceous with darker rusty brown lateral sigilla. In live specimen, parapsidal suture is pale ochraceous, bordered with dark rusty brown towards the submedian sigilla (Image 2). In dry specimen, however, the entire submedian sigilla appears darker, same as lateral sigilla. Dark scutal depressions appear as two black spot at the lower part of mesonotum, right above scutellum. Metanotum entirely rich ochraceous with darker scutellum. Both forewings and hindwings are entirely transparent without any infuscation. Veins dark brown, almost black. Basal cell, basal membrane of the forewing and jugal fold, jugum of hindwing pale castaneous. Coxa of all the legs are greyish castaneous. Primary and secondary spine of fore femur is reduced and appears as rudimentary nodule. Tibia in second and third pair of legs are rich ochraceous but paler than the segments beyond it. The tibia in forelegs is darker and more rich in colour compared to the tibia of rest of the legs. Globose operculum uniformly pale castaneous, short and broad, visible from dorsal side.

Abdomen: Abdomen pale castaneous; apical area of abdomen castaneous (Distant 1906). Abdomen uniformly castaneous in live and freshly preserved specimen but in old preserved specimen the colour of apical region appears richer. Timbal entirely covered by round and globose timbal cover. Prominent lateral black spots on both sides of 3rd to 7th tergite. On the 8th tergite, the black spot shifts up and appear as dorsolateral spots.

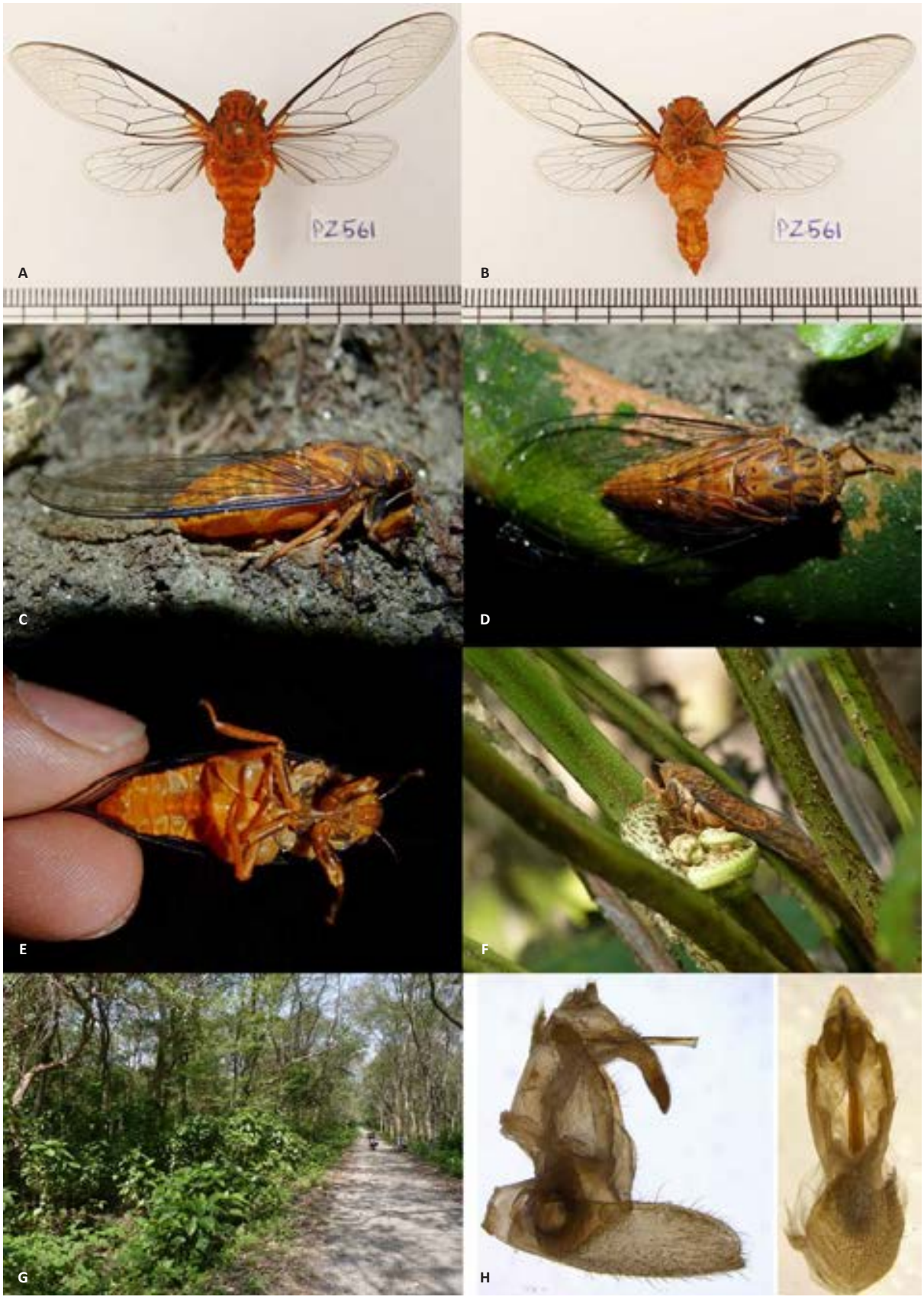

Image 2. *Lahugada dohertyi*: A—dorsal view | B—ventral view | C–E—live specimen | F—species feeding on *Diplazium* sp. | G—habitat | H—male genitalia. (A,B,H © National Centre of Biological Sciences, Bangalore, and photographed by Dipendra Nath Basu; C–G © Vivek Sarkar).

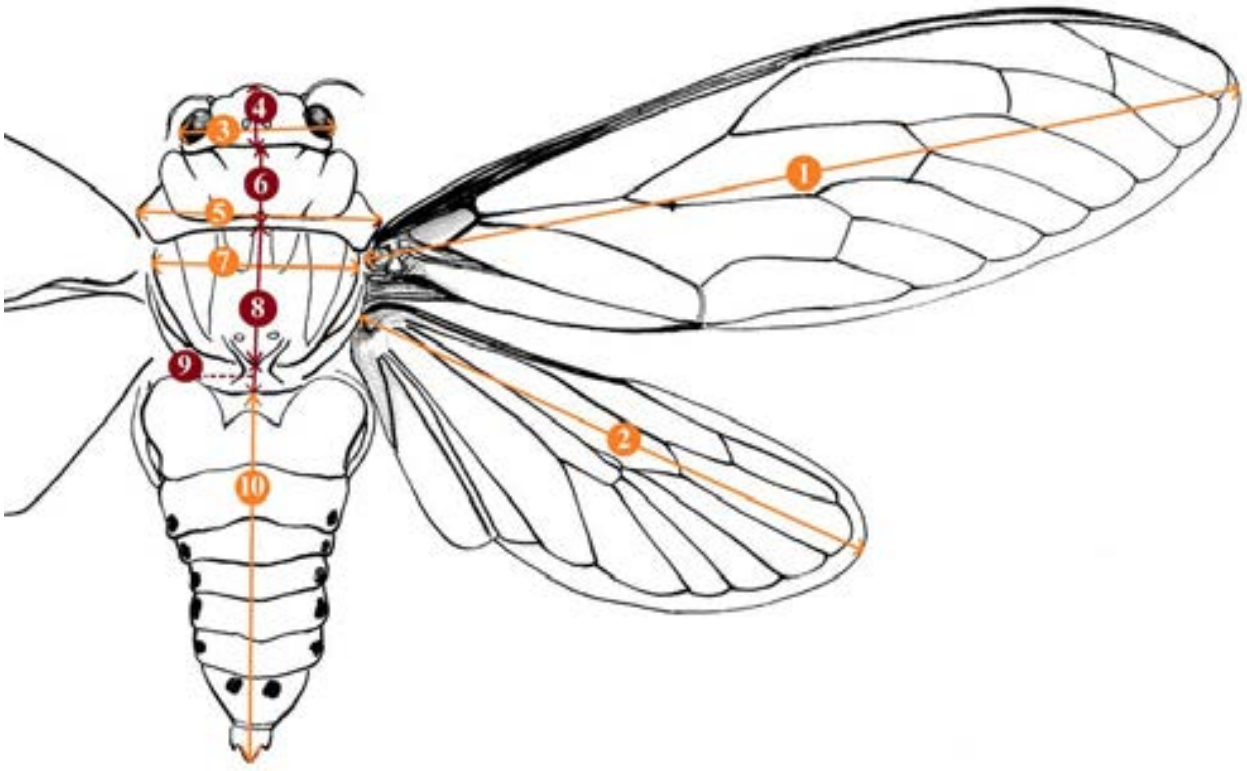

Figure 2. *Lahugada dohertyi*: 1—length of the forewing | 2—length of the hindwing | 3—width of the head from eye to eye | 4—length of the head from the frontal part of postclypeus to the back of the head | 5—width of the pronotum from one lateral angle of pronotal collar to another | 6—length of the pronotum from the back of the head to the lower end of pronotal collar | 7—width of the mesonotum | 8—length of the mesonotum from the lower part of the pronotum collar to the upper groove of the scutellum | 9—length of metanotum | 10—length of abdomen starting from the lower part of scutellum to the tip of the anal style. © Vivek Sarkar.

Table 2. General measurements of the collected specimen.

	Body part	Measurement of NCBS-PZ561	Measurement of NCBS-PZ562
1	Forewing	34.020mm	35.592mm
2	Hindwing	20.996mm	21.620mm
3	Width of the head	6.141mm	6.058mm
4	Length of the head	1.780mm	1.887mm
5	Length of Proboscis	4.704mm	4.606mm
6	Width of pronotum	8.740mm	9.371mm
7	Length of pronotum	3.124mm	3.284mm
8	Width of mesonotum	7.781mm	7.640mm
9	Length of mesonotum	4.842mm	4.580mm
10	Length of metanotum	1.246mm	1.166mm
11	Length of abdomen	17.657mm	14.710mm

Male genitalia: This is the first-ever description of the male genitalia of this species, which has been missing even in the original description. Pygofer looks oblong and triangular laterally with broader base and narrower top towards the distal beak. Basal lobe and upper lobe of pygofer prominent. Basal lobe covering more than one-third of the pygofer length, from base to the distal end ventrally and rest is upper lobe till the distal end. Dorsal beak small, barely touches anal tube. Dorsal shoulder narrowly present between dorsal beak and upper lobe of the pygofer. Anal tube is compressed and appears as a thin disk below anal styles which is at the distal-most end. Median lobe of uncus prominent and protruding out like an anchor. The tip of the median lobe bifurcated, forms to oblong conical claspers. The aedeagus protrudes out from the base of the bifurcation of the median lobe of uncus.

B. Collected specimen

Six specimens (four males and two females) were collected by me from the outskirts of Coochbehar (26.3330N & 89.4660E, 46m) in May 2014. Later in the same month, one male was collected after dark, from the corridor of Panchayet Block office, Pundibari, Coochbehar (26.3330N & 89.4660E, 52m). Two females and three males were preserved in alcohol and two males were pinned and preserved (in dry condition)

which are represented in this paper (Specimen Voucher number: NCBS-PZ561 and NCBS-PZ562).

C. General measurements (Fig. 2; Table 2)

NCBS-PZ561, adult, male, 10.5.2014; NCBS-PZ562, adult, male, 11.5.2014.

D. Bionomics

Habitat type: This cicada is locally common. Due to its high relative abundance, the species was mostly seen throughout northern Bengal but only in a particular habitat, i.e., undisturbed mixed forest with thick undergrowth of *Dendrocnide sinuate* along with *Diplazium* sp. (Image 2). Apart from its type locality, the species was also reported from Manas Tiger Reserve (Price et al. 2016) by Dr Krushnamegh Kunte, who also found it in the same habitat type (Fig. 1).

Activity period: The cicada was opportunistically found in 2014 in northern West Bengal and hence its activity period could not be studied initially. In 2016, an attempt was made to record its activity period. It was observed that the first individual emerges in the third week of April, during the pre-monsoon rains. The maximum individuals were heard between the first and third week of May and the last individual was encountered in the first week of June.

Behaviour: The call is similar to random clicks for some time and the duration of the call varies from 20s to 1min 10s, if not disturbed (n=22). It mostly calls by sitting in one place but it has also been observed to occasionally fly in a circle, 0.6–1.2 m above the ground, with typical clicking-like echemes. It repeats this circling flight five to nine times during one complete call and settles down toward the end of the call. It continues calling for some time and then remains silent until the next calling session starts. The radius of this circular flight varies from 2.5m to 4.5m approximately, and it occasionally takes the same path repeatedly for this circular flight. On occasion, it was observed that the individuals were flying without any particular route or pattern. Mostly, the males rest on the ground or within 0.5m from the ground in the middle of Ground Fern *Diplazium* sp., which makes them difficult to spot. It has also been observed that the males can be as far as 6ft away from the ground, and not beyond, while resting. Females, however, settle in the lower part of the thick bushes of *Dendrocnide sinuate*, which makes them even more difficult to spot. Males and females, have been observed feeding mostly on *Dendrocnide sinuate* and Ground Fern *Diplazium* sp. (Image 2) and occasionally on wild Eggplant *Solanum* sp. This cicada is not often attracted to light but occasionally comes to light if disturbed after dark.

Larval morphology

The final instar nymph climbs the tree trunk for eclosion and settles between 304–457 mm above the ground. The intermediate tooth of the femur is adjacent to the femoral comb and almost appears as the most prominent tooth of the comb. The femoral comb consists of four prominent teeth and one incomplete tooth towards the joining of the femur with tibia. Accessory tooth of femur is rudimentary and appears as a small nod below the tip of stocky posterior tooth of femur. The apical tooth of tibia is not too long but rather short and stout. The point of the blade of the tibia is outwardly depressed in the middle but appears straight from the inner side. Spines are prominent at the apex of mid and hind tibiae of final instar nymph and are almost identical.

Proposed common name

Based on its appearance and behaviour, the name 'Ochre Summer Clicker' seems appropriate for this species.

Justification

- This species of cicada is ochraceous in its general appearance, which literally means ochre-coloured.

- This cicada is broadly found in the mixed forests and wet deciduous forests in summer, right after the April rains.

- The call of this cicada is typically click-like.

Due to these characteristics, the proposed name seems informative and is hence suggested for common use.

DISCUSSION

As of now, according to my understanding, the species has a strong association with its habitat as it was found in the same type of habitat throughout its range in northern West Bengal. It would have been a great help in understanding its biology if one could get an account of the habitat where William Doherty collected the type specimen from. The type locality as well as the other parts of Assam should also be surveyed to know more about the biology of this species. Population data of this cicada could not be collected adequately and uniformly due to its habitat preference with *Dendrocnide sinuate.* Physical contact with the leaf of *Dendrocnide sinuate* causes rashes and skin irritation, restricting the

Image 3. ***Lahugada dohertyi*** **larval exuviae: A—dorsal view | B—lateral view | C—ventral view | D—closeup of head from below | E—foreleg | F—mid-leg | G—hind leg | H—closeup of the abdominal apex. © Vivek Sarkar.**

movement of the observer and limiting access to the interior part of the bushes. A small, isolated population of this cicada was found in Chakchaka suburb in May 2014, as mentioned earlier in the text. Despite being private property, the locality had a similar habitat with very little human activity at that time. In November 2014, the entire patch along its adjacent area was completely cleared and dug up for house construction and Betel Nut *Areca catechu* plantation. In May 2015, no calls of *Lahugada dohertyi* were heard in and around the Chakchaka suburb though the individuals of *Dundubia* sp. remained at large in the same area. Another active search attempt was made in April–May 2016 but no *Lahugada* was heard or spotted in the suburb though multiple individuals were spotted in other localities of northern West Bengal, both in 2015 and in 2016. This is merely an observation and unless more data on its natural history such as host plant and larval behaviour is acquired, it would be impossible to narrow down and identify the potential threats to this species. It would also be a challenge to describe its tymbalization as the cicada calls during its skittish, shuddering, circular flight, which makes it difficult to record its complete call with parabola and microphone, and hence a different method has to be adopted.

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Observations on nesting activity, life cycle, and brood ball morphometry of the Bordered Dung Beetle *Oniticellus cinctus* (Fabricius, 1775) (Coleoptera: Scarabaeidae) under laboratory conditions

Amar Paul Singh [1], Kritish De [2], Shagun Mahajan [3], Ritwik Mondal [4] & Virendra Prasad Uniyal [5]

[1,2,5] Department of Landscape Level Planning & Management, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India.
[1,4] Department of Zoology, University of North Bengal, Darjeeling, West Bengal 734013, India.
[3] Department of Zoology, Alpine Institute of Management and Technology, Dehradun, Uttarakhand 248007, India.
[1] amarpaulsingh4@gmail.com, [2] kritish.de@gmail.com, [3] shagunmahajan2017@gmail.com,
[4] ritwik.uk12@gmail.com (corresponding author), [5] uniyalvp@wii.gov.in

Abstract: The nesting activity, life cycle, and brood ball morphometry of the dung beetle *Oniticellus cinctus* (Fabricius, 1775) (Coleoptera: Scarabaeidae) were studied under laboratory conditions for the first time in India. The females made a brood chamber within the dung mass provided, wherein they made brood balls to lay eggs. The life cycle includes egg, larva (three instars), pupa, and adult stages. The total duration for the development was about one month. The study found that there was a significant difference present in the brood ball diameter (except in the first and second instars) and brood ball weight (except in the second instar and pupa) of the six life cycle stages. It was also found that brood ball weight and diameter have a significant positive correlation as well as a linear relationship.

Keywords: Morphometry, nidification, scarabaeid beetle, Scarabaeinae, weight-diameter relationship.

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Author details: Amar Paul Singh was a postgraduate (zoology) student and he is presently working as a researcher. His research interests include diversity, taxonomy, ecology and behaviour of insects particularly in beetles. Kritish De is presently working as a researcher and his research interests include diversity and ecology of insects. Shagun Mahajan was a postgraduate (zoology) student and she is interested in the field of biodiversity and ecology. Ritwik Mondal is working as an assistant professor. He has previous research experience in the field of mosquito ecology, vector biology and fish toxicology. His current research interest is in the field of molecular taxonomy of arthropods and fish as well as in the physiological and genotoxic effects of insecticides and pesticides on fish. Virendra Prasad Uniyal is working as Senior Professor and Scientist G. He is a Fellow of The Royal Entomological Society, London. His research interests include ecology and systematic of insects, bioindicators, biodiversity surveys and ecological monitoring in western Himalayan protected areas.

Author contribution: APS—collection of samples, laboratory work, and preparation of the manuscript; KD—laboratory work, data analysis, and preparation of the manuscript; SM—collection of samples and laboratory work; RM—designing the study, directing and supervising laboratory work and data analysis, and preparation of the manuscript; VPU—designing the study, directing and supervising laboratory work and data analysis, and preparation of the manuscript.

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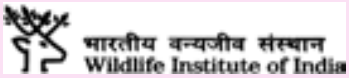

INTRODUCTION

The coleopteran insects (beetles) belonging to the subfamilies Aphodiinae and Scarabaeinae under the family Scarabaeidae are commonly called dung beetles as they feed primarily on mammalian dung and also use it for providing nesting and food for their larvae. The beetles of the subfamily Scarabaeinae are well-represented insects in the tropical regions (Filgueiras et al. 2009). Both sexes of the adults were identified with the help of published taxonomic keys (Chandra & Gupta 2013).

Globally, some studies have been done to understand nidification of dung beetles. Klemperer (1982a,b,c, 1983a,b,c, 1984) studied the nesting behaviour of several species of dung beetles. Biscoe (1983) studied the effects of ovarian condition on the nesting behaviour of *Copris diversus* Waterhouse, 1891. Sato & Imamori (1987) studied the nesting behaviour of the African Ball-roller *Kheper platynotus* (Bates, 1888). Edwards & Aschenborn (1987) studied patterns of nesting and dung burial in *Onitis* dung beetles. Davis (1989) studied nesting of the Afrotropical *Oniticellus* and its evolutionary trend from soil to dung.

So far, there are no studies to understand the morphometry of brood balls (the round-shaped ball made up of dung constructed by the female to lay eggs within it) as well as the weight-diameter relationship of different life cycle stages of *Oniticellus cinctus* from India.

MATERIAL AND METHODS

The study was carried out from the first week of May to the end of the second week of June 2017 for a period of about six weeks. The adults (both males and females) of *Oniticellus cinctus* were collected from dung that was 2–3 days old using hand-sorting method and were transported to the laboratory of the zoology department, Alpine Institute of Management and Technology, Dehradun.

Five pairs of beetles (one male and one female in each pair) were chosen for the study. Five rearing trays, each of 40cm (L) × 30cm (W) × 15cm (H) size were set up and filled up to two-thirds with a mixture of soil and sand. The mixture was moistened with the requisite amount of water. For the maintenance of adequate temperature, humidity, and darkness, each rearing tray was covered with inverted earthen pots. One pair of adults (one male and one female) was released in each tray. Fresh cow dung was provided and the old dung replaced daily.

After about six days from the release of the adults in the rearing trays, the nest construction occurred. A total of 50 brood balls (10 from each pair in each tray) were selected for our study; the rest of the brood balls were removed from the tray. Regular observations were conducted once a day (at 08.00h) by opening the brood balls to observe the development of the individual from egg to adult stage. The opening in the brood balls was immediately sealed after observation with the help of fresh dung. The weight and diameter of the brood balls were taken on the final day of each developmental stage by Kerro laboratory analytical balance (accuracy 0.01gm) and Mitutoyo digital vernier calliper.

One-way ANOVA followed by post hoc Dunn's test was performed to find out the presence of a significant difference (if any) in the diameter and weight of brood balls between lifecycle stages. Pearson's product-moment correlation coefficient (r) was calculated to explore the strength of association between the diameter and weight of brood balls between lifecycle stages. Linear regression model between diameter and weight of brood balls in different life cycle stages was calculated. All the statistical analysis was performed using R version 3.3.1 (R Core Team 2016).

RESULTS

The life cycle of *Oniticellus cinctus* includes egg, three larval (first, second, and third instar) stages, pupal stage, and adult.

The body of the adult (Image 1A) is dorsoventrally compressed and oblong and the colour is shiny black. The head is shining, smooth, and without any carina (elevation or ridge of the cuticle). The antennae are 8-segmented. The scutellum is visible. The pronotum is smooth and a deeply impressed median longitudinal line is present upon its posterior half. The elytra (external and sclerotized forewings) are deeply striated and each elytron has a pale yellow external border. Fore tibia of the male have small inner teeth with inner spur while that of the female have broad inner teeth and no spur.

The female mangled the dung gradually to prepare a lopsided (one side lower or smaller than the other) chamber initially. Finally, a hollow chamber (called brood chamber) of around 6–10 cm in width, 4–8 cm in height, and 5–7 cm in depth was constructed to store brood balls within the provided dung mass (Image 2). The females used prothoracic legs (Image

Image 1. *Oniticellus cinctus*: A—Adult male and female | B—Prothoracic leg of adult male and female.

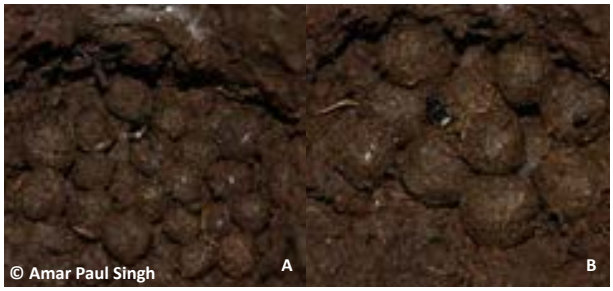

Image 2. Brood chamber of *Oniticellus cinctus*: A—Initial brood balls | B—Final brood balls.

Image 3. Egg of *Oniticellus cinctus* within the brood ball.

1B) for the construction of the brood chamber or nest. Approximately 12–20 brood balls were constructed by each female and one egg was laid within each brood ball. The female beetle was present in the chamber during the entire period of the brood development. It also applied fresh dung on the brood ball during the entire period of the brood development and made the next nest after the development was completed.

Eggs were cylindrical and white or creamy and only one egg was present in each brood ball (Image 3). Egg development was completed and the larva hatched within 3–5 days (mean = 4.2 days, SD = 0.75; Fig. 1).

Three larval stages, namely first instar larva (Image 4), second instar larva (Image 5), and third instar larva (Image 6), were observed. The developmental time for the first, second, and third instars was 1–3 days (mean = 2.32 days, SD = 0.68), 1–3 days (mean = 2.24 days, SD = 0.74), and 10–16 days (mean = 13.52 days, SD = 1.52), respectively (Fig. 1). Larvae were C-shaped with a projecting hump, light grey; the head was somewhat light orange. Four segmented antennae and two segmented legs were present. Maxilla with galea and lacinia were distinctly separated in the larva.

The pupa (Image 7) was whitish and appeared pointed from the posterior portion. A large and blunt pronotal projection extended over a posterior portion of the head. Pupa development was completed within 4–8 days (mean = 5.58 days, SD = 1.2; Fig. 1).

The adult remained in the brood ball for 1–3 days (mean = 2.24 days, SD = 0.72; Fig. 1), after which it emerged. The total duration of the development was about one month (mean = 30.08 days, SD = 5.35).

Mean weight and diameter of the brood balls on the final day of egg development (freshly-hatched larva) were 0.27g (SD = 0.11; Fig. 2) and 6.25mm (SD = 1.24; Fig. 3), respectively. Mean weight and diameter of the brood balls on the final day of the first instar larval development was 0.50g (SD = 0.15; Fig. 2) and 9.55mm (SD = 1.48; Fig. 3), respectively. Mean weight and diameter of the brood balls on the final day of second instar larva development was 1.14g (SD = 0.30; Fig. 2) and 10.046mm (SD = 1.02; Fig. 3), respectively. Mean weight and diameter of the brood balls on the final day of third instar larval development was 1.83g (SD = 0.31; Fig. 2) and 12.012mm (SD = 1.47; Fig. 3), respectively. Mean weight and diameter of the brood ball on the final day of pupa development was 1.11g (SD = 0.23; Fig. 2) and 15.018mm (SD = 0.66; Fig. 3), respectively. Mean weight and diameter of the brood balls where freshly developed adults rested was 0.66g (SD = 0.26; Fig. 2) and 15.294mm (SD = 0.71; Fig. 3), respectively.

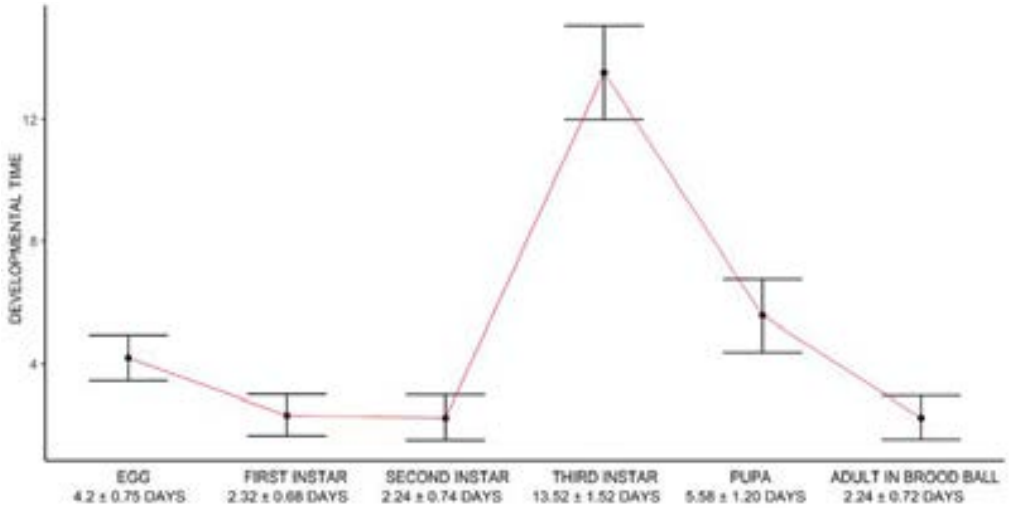

Figure 1. Comparative account of the mean developmental time of different life cycle stages of *Oniticellus cinctus*.

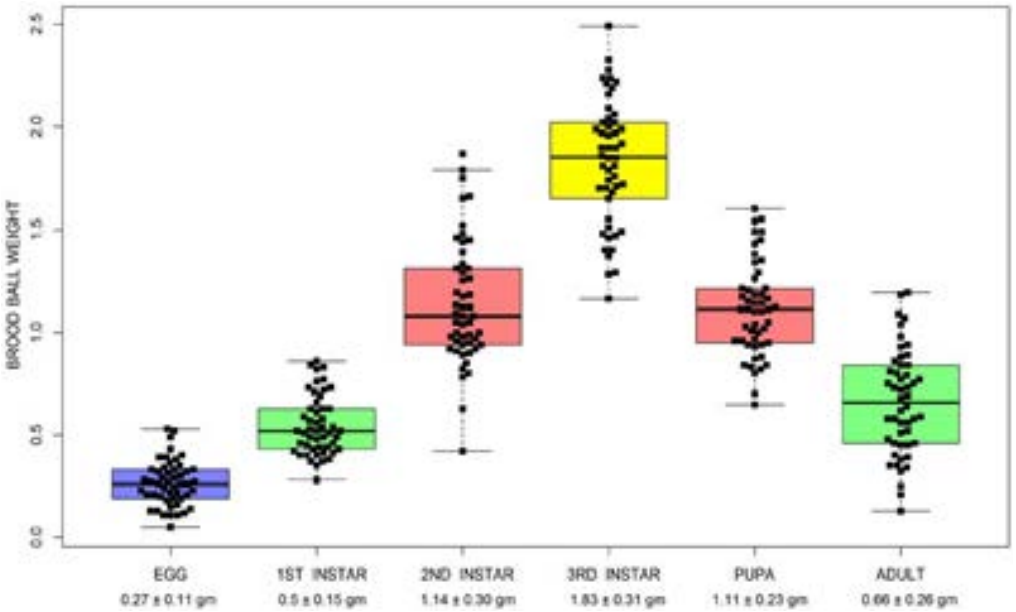

Figure 2. Comparative account of brood ball weight of different life cycle stages of *Oniticellus cinctus*. Life cycle stages marked by similar colour had no significant difference in the mean weight of the brood balls (post hoc Dunn's test, p > 0.05).

The result of one-way ANOVA showed that there was a significant difference present in the brood ball weight of the six life cycle stages ($F = 279.24$, $df = 5,294$; $p < 0.05$). The result of post-hoc Dunn's test suggested that there was no significant difference (at $\alpha = 0.05$) present in the brood ball weight of the second instar and pupa (z score = -0.066, $p = 0.474$; Fig. 2).

The result of one-way ANOVA showed that there was a significant difference present in the brood ball diameter of the six life cycle stages ($F = 458.84$, $df = 5,294$; $p < 0.05$). Result of post-hoc Dunn's test suggested that there was no significant difference (at $\alpha = 0.05$) present in the brood ball diameter of first instar and second instar (z score = -0.843, $p = 0.1995$) and of pupa and adult (z score = -0.594, $p = 0.276$; Fig. 3).

Pearson product-moment correlation between diameter and weight of brood balls in different life cycle stages was found to be significant ($p < 0.05$) and positive (Fig. 4). It was found that the weight of the brood balls of different life cycle stages had a simple linear relationship with the diameter of the brood balls (Fig. 4).

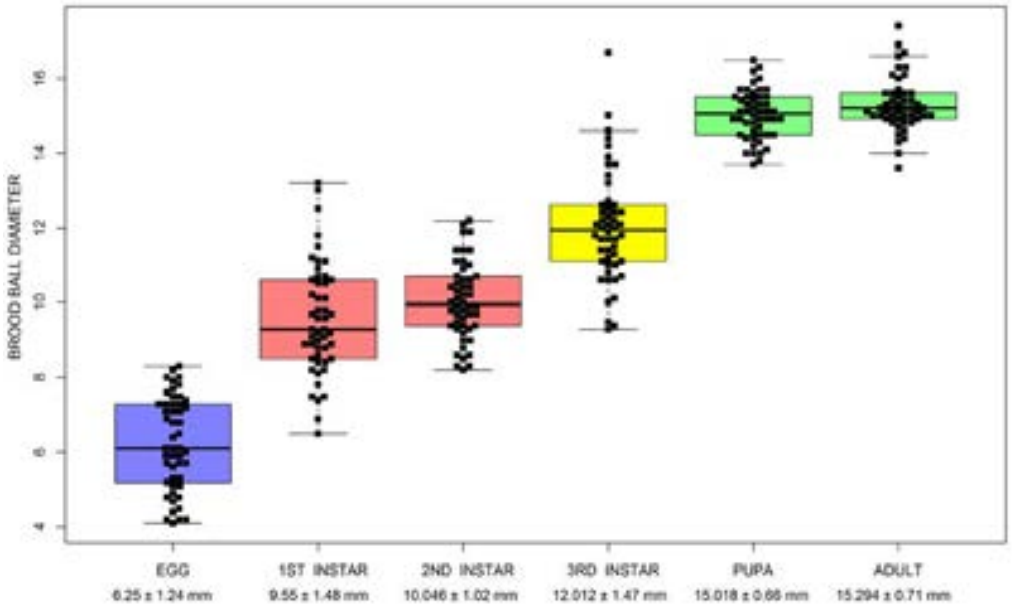

Figure 3. Comparative account of brood ball diameter of different life cycle stages of *Oniticellus cinctus*. Life cycle stages marked by similar colour had no significant difference in the mean diameter of the brood balls (post hoc Dunn's test, p > 0.05).

Image 4. First instar larva of *Oniticellus cinctus* within the brood ball.

Image 5. Second instar larva of *Oniticellus cinctus* within the brood ball.

DISCUSSION

Three groups of dung beetles are distinguished based on their behaviour in creating a brood mass, namely teleocoprids, paracoprids, and endocoprids (Ridsdill-Smith 2003). Teleocoprid dung beetles make balls of dung and roll the dung ball away from the dung pat and bury it in soil. Paracoprid dung beetles dig a tunnel in the soil under the dung pat, carry small piece of dung down that tunnel, and pack in to the end as a compacted brood mass. Endocoprid dung beetles construct brood balls in cavities within the dung pat (Ridsdill-Smith 2003). *Oniticellus cinctus*, which was chosen for the study, is an endocoprid dung beetle. This genus belongs to the variation 1 of Group 1 nidification category (Halffter & Matthews 1966) because the female prepares a small

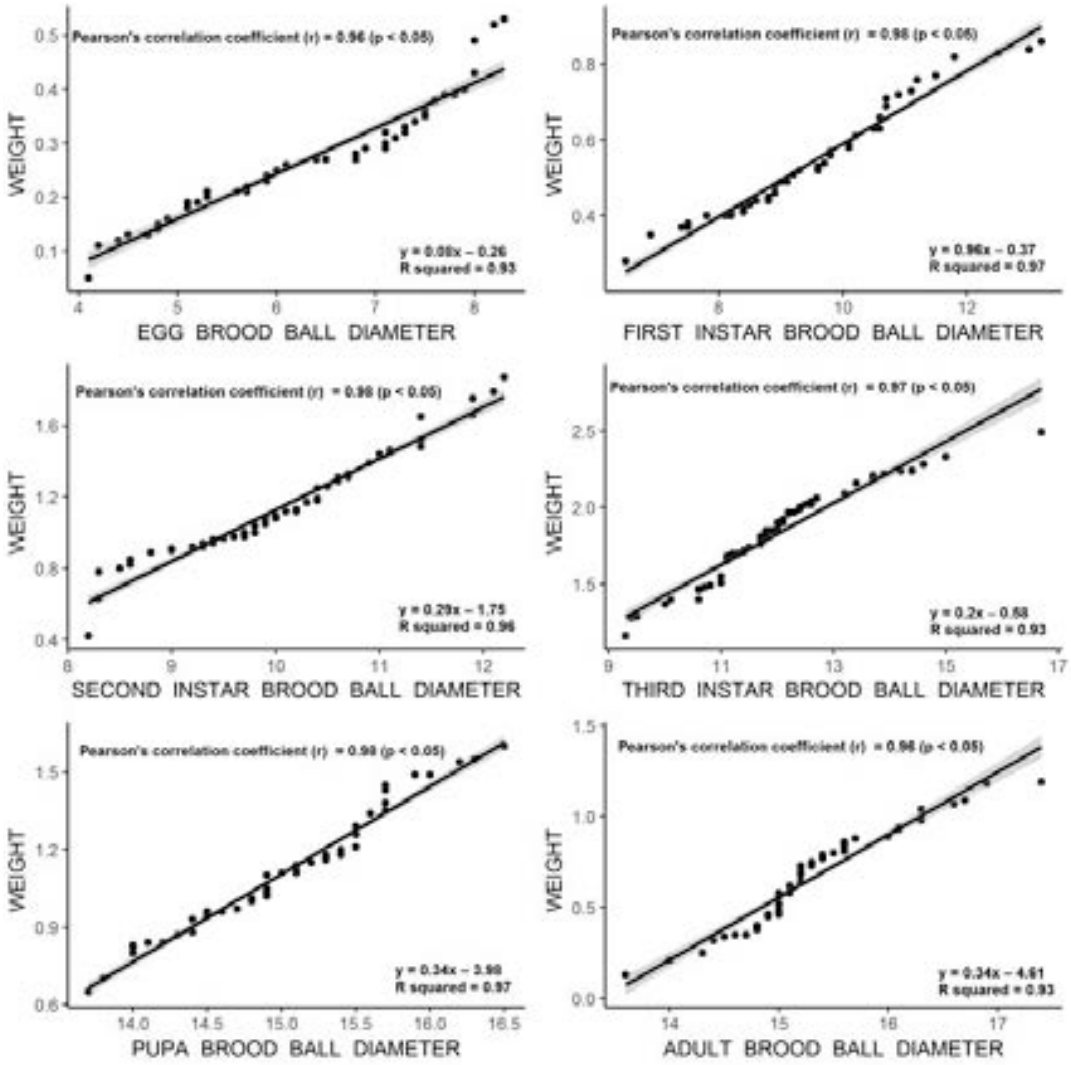

Figure 4. Pearson's product moment correlation and linear regression model between weight and diameter of brood balls in different life cycle stages of *Oniticellus cinctus*.

Image 6. Third instar larva of *Oniticellus cinctus* within the brood ball.

Image 7. Pupa of *Oniticellus cinctus* within the brood ball.

dung mass and lays one egg in each under the food source, i.e., the dung.

The present study found that the life cycle of *Oniticellus cinctus* is completed within six weeks with egg, three larval stages (first, second, and third instar), pupa and adult stages, of which duration of third instar larva is maximum.

By performing one-way ANOVA, it was found that the mean weight and mean diameter of the brood balls of different life cycle stages had significant differences; however, as it is an omnibus test, it did not specify which stage of the life cycle had different mean weight and mean diameter of the brood balls. Post hoc Dunn's test was performed to overcome this issue. It was found that there was no significant difference in brood ball diameter of first instar and second instar and of pupa and adult and there was no significant difference in brood ball weight of second instar and pupa and of first instar and adult. As correlation and simple linear regression models are two ways of exploring a potential linear relationship between the values of the two traits (Puth et al. 2014), these methods were applied to find the relationship between diameter of the brood balls of different life cycle stages of *Oniticellus cinctus*; it was found that weight and diameter of brood balls had significant ($p < 0.05$) positive correlation and they fit the simple linear model.

Previously only Klemperer (1983b) had studied the effect of the brood on parental care and oviposition of this dung beetle species. The present study had similarities with the study by Klemperer (1983b) in terms of morphometry of brood balls and developmental times for different life cycle stages. The present study reported the use of prothoracic legs by female to built brood chamber or nest. Klemperer (1983b) found that often a male adult was present in the nest when several beetles were present in the experimental setup. But the present study did not observe such thing, most probably because of only one pair of adult beetles (one male and one female) was released in each rearing tray for the study.

It is necessary to study the nidification of dung beetles of all three behavioural categories (teleocoprids, paracoprids, and endocoprids) in both laboratory and field conditions, especially the field-level nidification and brood ball morphometry studies in different seasons and habitats.

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Spiders of Odisha: a preliminary checklist

Sudhir Ranjan Choudhury [1], Manju Siliwal [2] & Sanjay Keshari Das [3]

[1,3] University School of Environment Management, Guru Gobind Singh Indraprastha University, Sector 16-C, Dwarka, New Delhi 110078, India.
[2] Wildlife Institute of India, Post Box #18, Chandrabani, Dehradun, Uttarakhand 248001, India.
[1] sudhirranjanchoudhury@gmail.com, [2] manjusiliwal@gmail.com, [3] skdasipu@gmail.com (corresponding author)

Abstract: The present checklist of spiders of Odisha is the result of the compilation of all published literature on spiders and primary data collected during the present study carried out from July 2016 to March 2017 in Odisha. A total of 138 species of spiders belonging to 95 genera and 33 families were recorded in the present study. Of which, seven families, 36 genera and 80 species of spiders were reported for the first time from Odisha. Of these 80 species, 78 spider species were exclusively reported from the Eastern Ghats of Odisha. With this study, spider diversity of Odisha comprised of 248 species belonging to 139 genera and 39 families. Whereas, Eastern Ghats of Odisha comprised of 181 species belonging to 109 genera and 35 families. Of total spiders from Odisha, 23 species were found to be endemic to southern Asia, 49 species endemic to India and 19 species endemic to Odisha.

Keywords: Araneae, araneomorph, diversity, Eastern Ghats, endemic, mygalomorph, new records.

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Author details: Sudhir Ranjan Choudhury—is working as a senior research fellow. He is working on arachnid fauna of Odisha. Manju Siliwal—is an arachnologist having more than 20 years of experience on working on spiders. She specializes on mygalomorphs. Her work focuses on systematics, ecology, conservation and molecular phylogeny of mygalomorphs in India. Sanjay Keshari Das—is working as an Assistant Professor. His main interest is systematics, ecology and conservation of reptiles and arachnids.

Author contribution: SRC did majority of the collection of spiders from the field for the present study. He processed, photographed and identified spiders in the laboratory. He helped in compilation of this paper. MS carried out field surveys for collection of mygalomorphs along with SRC and SKD. She did confirmation of spiders and did help SKD and SRC in writing up this paper. SKD did major writing of this paper. He also carried out field surveys for spider collection in Odisha with SRC and MS.

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

INTRODUCTION

Spiders represent one of the most diversified groups amongst invertebrates and are ranked seventh in the global biodiversity, with 48,143 species under 4,131 genera and 117 families described from the World (Penney et al. 2003; WSC 2019). About 1,909 species belonging to 488 genera and 64 different families have been reported from India (WSC 2019), of which, about 115 species in 33 genera and eight families are of mygalomorph spiders and the rest of the species are of araneomorph spiders (WSC 2019). This number is very much underestimated and many more species are waiting to be discovered in the country because till date spider studies in India have been restricted to a few areas in the absence of systematic spider surveys for most of the states in India (Sebastian & Peter 2009).

Bio-geographically, Odisha (17.802–22.563 ^{0}N and 81.383–87.482 ^{0}E) is an important region as it has faunal representation from the north-east, the Eastern and Western Ghats (Aditya 2015). The diverse habitat supports a good faunal diversity in the State (Anon. 1987, 1989, 1990, 1993). However, spider fauna of Odisha is poorly studied like other parts of India with obscure and sporadic records of this group from various parts of the state**.** The first spider reported from Odisha was a mygalomorph spider, *Diplothele walshi* by O. Pickard-Cambridge (1891), later, Gravely (1921, 1931) added 51 species of spiders to it, which included both araneomorphs and mygalomorphs. Subsequent additions to the list of spiders were by Biswas (1975, 1987), Gajbe (1979), Tikader & Malhotra (1980), Tikader (1982), Majumder & Tikader (1991), Ramakrishna et al. (2006), Molur et al. (2008), Siliwal & Molur (2008), Siliwal et al. (2009a,b, 2010), Panda et al. (2011), Gupta et al. (2013, 2015), and Mohapatra et al. (2014), adding almost 100 species to Gravely's (1921, 1931) contribution. Considering the shortcomings of previous studies, systematic surveys were carried out to document spider diversity from different parts of Odisha.

MATERIALS AND METHODS

Study area

The present study was carried out mainly in the Eastern Ghats of Odisha with a few surveys outside the Eastern Ghats (Fig. 1, Table 1).

The Eastern Ghats represent a discontinuous range of mountains (also known as Malyadri) situated along the eastern coast of India and is one of the important physiographic units with great environmental, socio-economic, cultural and spiritual significance in the peninsular region of our country (Sinha 1971). The Eastern Ghats start in West Bengal and the mountain range continues to pass through Odisha, Andhra Pradesh, Karnataka, and Tamil Nadu. The Eastern Ghats of Odisha (Fig. 1) represent the northern Eastern Ghats. Based on geological and tectonic considerations, the Eastern Ghats in Odisha start from north of Similipal in Mayurbhanj District and run through Malkangiri covering 18 districts of Odisha (Dash et al. 2009). Mountain peaks and foot hills have contrasted weather resulting into a humid habitat in high altitudes to a semiarid habitat in foot hills. Vegetation of this region comes under the northern tropical moist deciduous forests. Physio-geographically, this region is divided into five sub regions: 1. the Similipal and Meghasani mountain, 2. the Mankarnacha-Malaygiri and Gandhamardan mountains of the Baitarani and the Brahmani interfluve, 3. the watershed between the Brahmani and the Mahanadi, 4. the common interfluves of the Mahanadi, the Rushikulya and the Vamsadhara, and 5. the Potangi and Chandragiri mountain ranges. The highest mountain peak is Deomali (1672m), which is situated in the Koraput District of southern Odisha. It is part of the Chandragiri-Pottangi mountain system that forms part of the Indian Peninsula and was a part of the ancient land mass of Gondwana land. Being physio-geographically heterogeneous, the Eastern Ghats of Odisha represent one of the biodiversity-important ecoregion. It is also rich in iron ore and minerals and supports a rich ethnic diversity (Sinha 1971; Dash et al. 2009).

Methods

Spider collection was done from July 2016 to March 2017 covering all seasons (monsoon: July to October; winter: November to February; and summer: March to June). Various sampling methods, viz., vegetation beating, pitfall trapping, sweep-netting, hand-picking, and leaf litter sampling (Koh & Ming 2013) were used to collect spiders. Two to four persons were engaged in active searching for spiders and a total of 1,000 man-hours were spent on collecting spiders in the study area during the entire study period. All possible habitats, viz., dense forest, open forest, wetlands, scrub lands, hill forests, agricultural fields and human settlements were covered in the present study. Specimens, after collecting were preserved in 70% alcohol. All mygalomorph specimens were deposited at Wildlife Information Liaison Development Society (WILD) museum, Coimbatore and all araneomorph specimens were

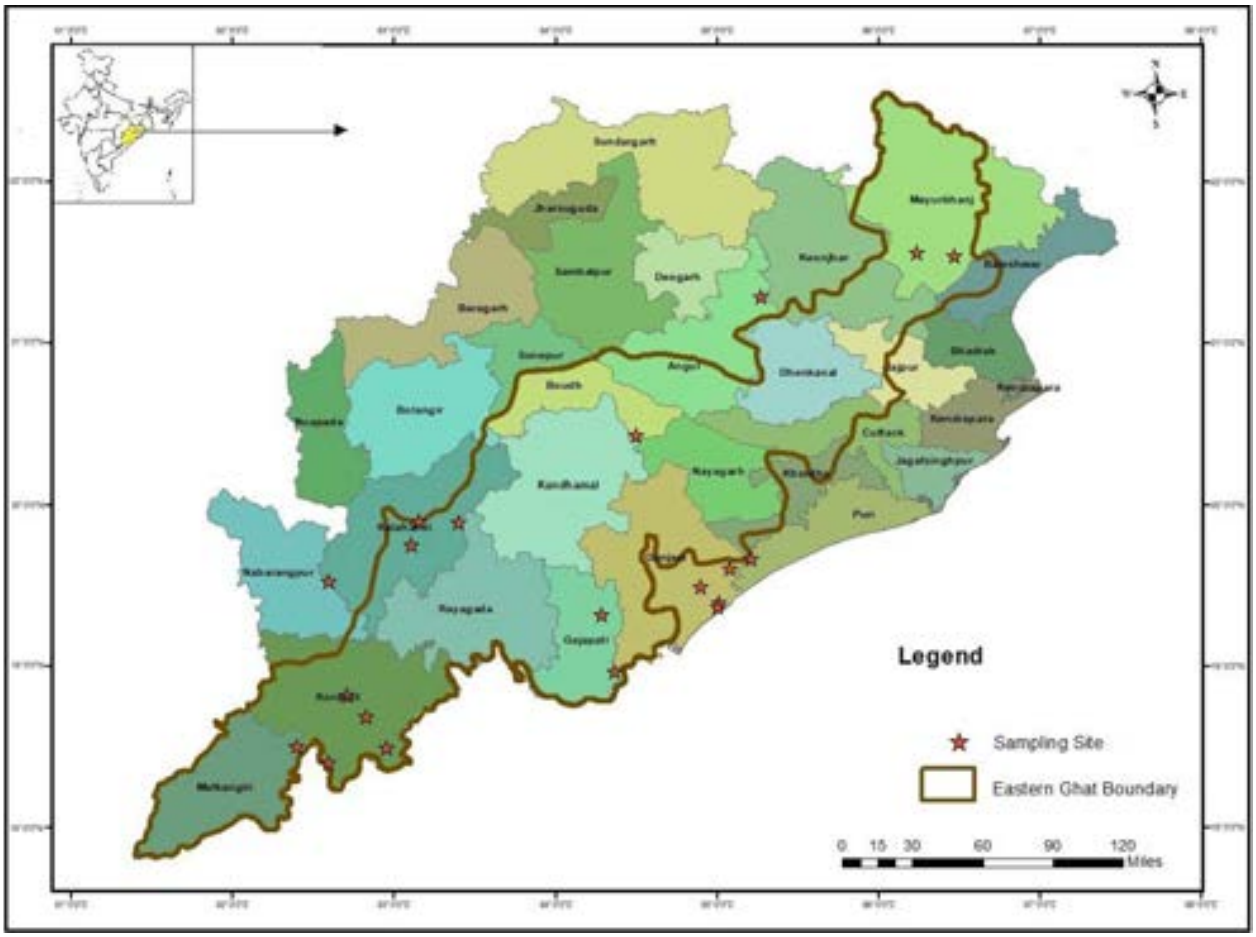

Figure 1. Study area (Source: http://eptrienvis.nic.in).

Table 1. Sampling sites during the present study.

	District	Sampling sites
1	Anugul	Satakosia Wildlife Sanctuary
2	Gajapati	Chandragiri, Mahendragiri
3	Ganjam	Ardheswar Temple, Chilika Lake, Gupteswer Temple (Near Balugaon), Kholikot, Makereswer Temple, Ramchandi Temple, Tampara, Taratarini.
4	Kalahandi	Ampanighati, Bhawanipatna, Karlapat Wildlife Sanctuary
5	Keonjhar	Kanjipanighati
6	Koraput	Deomali, Gupteswer Temple, Jeypore Ghati, Koraput Town, Semiliguda
7	Mayurbhanj	Baripada, Similipal National Park
8	Rayagada	Muniguda

deposited at Indraprastha University (IPU) museum, Delhi. Spiders were identified examining the specimens under Olympus SZ10 stereozoom microscope. For identification, female genitalia were dissected and cleaned in concentrated lactic acid for 15–20 minutes. Identification was done using different publications by Tikader (1980, 1982, 1987), Tikader & Malhotra (1980), Barrion & Litsinger (1995), Song et al. (1999), Jocqué & Dippenaar-Schoeman (2006), Gajbe (2008), Sebastian & Peter (2009), and Metzner (2017).

Checklist of spiders of Odisha was prepared from the present study data and compiling the species from published literature (peer-reviewed journals) from the state on spiders. Papers published in predatory journals, or unpublished literature like Ph.D. thesis, post-graduation dissertations and newspaper articles were not included in the compilation of the present checklist.

RESULTS AND DISCUSSIONS

Before the present study, 168 species of spiders belonging to 103 genera and 32 families were reported from Odisha and of these, 103 species belonging to 68 genera and 24 families were reported from Eastern Ghats of Odisha (Pickard-Cambridge 1891; Walsh 1891; Gravely 1921, 1931; Biswas 1975, 1987; Gajbe 1979;

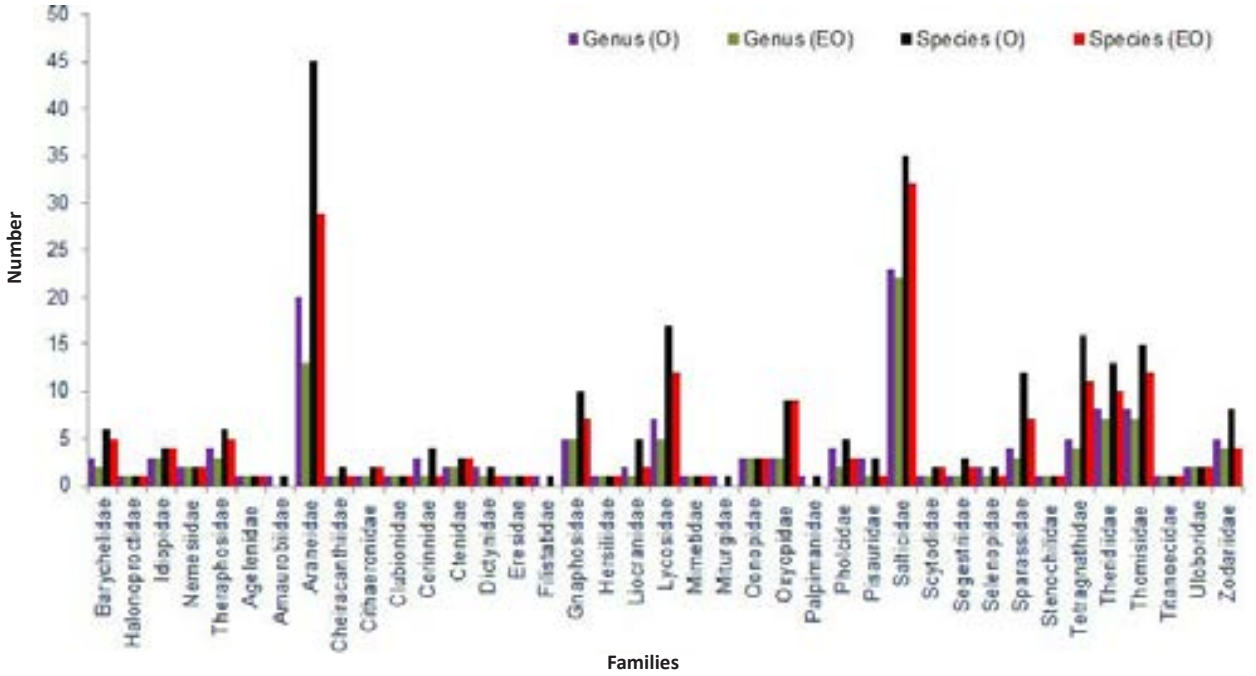

Figure 2. Spider diversity: Odisha (O) vs. Eastern Ghats of Odisha (EO).

Tikader & Malhotra 1980; Tikader 1982; Majumder & Tikader 1991; Ramakrishna et al. 2006; Molur et al. 2008; Siliwal & Molur 2008; Siliwal et al. 2009a,b, 2010; Panda et al. 2011; Gupta et al. 2013; Mohapatra et al. 2014) (Table 2, Figs. 2). Four species—*Cheiracanthium inclusum* (Hentz, 1847), *Oxyopes lineatipes* (C.L. Koch, 1847), *Oxyopes papuanus* Thorell, 1881, and *Uloborus barbipes* L. Koch, 1872—reported from the state by Panda et al. (2011) and Mohapatra et al. (2014), were probably identified based on photographs and seems to be a clear case of misidentification. So far, these species are known from outside India only. Hence, the present checklist did not consider these species in our checklist and these species need further taxonomic verification.

During the present study, 138 species of spiders belonging to 95 genera and 33 families were reported from Odisha. Of which, seven families, 36 genera and 80 species of spiders were reported for the first time from Odisha. Of these 80 species, 78 spider species were exclusively reported from the Eastern Ghats of Odisha. Here, we would like to make a note that in the present checklist 77 spiders are identified only up to genus level only (Table 2).

Based on all the compilation of previous reports and data from present study, the spider diversity of Odisha comprises 248 species belonging to 139 genera and 39 families and Eastern Ghats of Odisha 181 species belonging to 109 genera and 35 families (Table 2; Fig. 2, Image 1A–L). The study shows that over 72% of spiders reported from Odisha are found in the Eastern Ghats of Odisha (Table 2) and hence, the Eastern Ghats contribute largely to the spider diversity of Odisha.

Among the spiders reported in the present study, *Parasteatoda kompirensis* (Bösenberg & Strand, 1906) was reported for the first time from India (Malik et al. 2018) (Table 2). The study also reported two rare spiders—*Inthaeron* spp.—from Odisha, which will be published in different paper. Amongst these spiders reported in Odisha, species richness of family Araneidae (45 spp.) was found to be highest followed by Salticidae (35 spp.) and Lycosidae (17 spp.) (Table 2; Fig. 2). Of the total spiders from Odisha, 23 species were found to be endemic to South Asia and 49 species endemic to India. Of the spiders endemic to India, 19 species are reported from Odisha State only (Table 2).

Though the present study was for a short period and mostly restricted to the Eastern Ghats of Odisha, the findings of this study are significant, as during the study, 80 species for Odisha and one for India were added to the existing list for the first time. Therefore, there is a need to carry out systematic surveys in the entire state covering all the seasons to get an optimum estimate of spider diversity.

Table 2. Checklist of spiders of Odisha

	Species	Catalogue no.	Reference	Remarks
MYGALOMORPHAE				
Family Barychelidae Simon, 1889 (Trapdoor spiders)				
1	*Diplothele gravelyi* Siliwal et al., 2009	WILD-17-ARA-1482	Siliwal et al. 2009b; PS	#, E_O
2	*Diplothele* sp.	WILD-17-ARA-1463, 1486	PS	#, F_3, E_{SA}
3	*Diplothele tenebrosus* Siliwal et al., 2009	WILD-16-ARA-1380	Siliwal et al. 2009b; PS	#, E_O
4	*Diplothele walshi* O. Pickard-Cambridge, 1891		Walsh 1891**,** Gravely 1921; Siliwal & Molur 2008; Siliwal et al. 2009b	#, E_O
5	*Sasonichus* sp.	WILD-16-ARA-1381	Siliwal & Molur 2008; PS	#, E_I
6	*Sipalolasma arthrapophysis* (Gravely, 1915)		Gravely 1921; Siliwal & Molur 2008	E_O
Family Halonoproctidae Pocock, 1901 (Trapdoor spiders)				
7	*Conothele varvarti* Siliwal et al., 2009	WILD-17-ARA-1472, 1473, 1474	Siliwal et al. 2009a; PS	#, E_O
Family Idiopidae Simon, 1889 (Trapdoor spiders)				
8	*Heligmomerus barkudensis* (Gravely, 1921)	WILD-17-ARA-1454, 1455, 1457, 1481	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Siliwal et al. 2010; PS	#, E_I
9	*Idiops oriya* Siliwal, 2013		Gupta et al. 2013, 2015.	#, E_O
10	*Idiops* sp.	WILD-16-ARA-1400	PS	#, F_3
11	*Scalidognathus* sp.	WILD-16-ARA-1408; WILD-17-ARA-1453, 1456	PS	#, F_3, E_O
Family Nemesiidae Simon, 1889 (Wishbone spiders)				
12	*Damarchus* sp.	WILD-16-ARA-1382, 1383; WILD-17-ARA-1468	PS	#, F_3
13	*Gravelyia excavatus* (Gravely, 1921)	WILD-16-ARA-1396, 1397, 1398	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; PS	#, E_O
Family Theraphosidae Thorell, 1869 (Tarantula spiders)				
14	*Chilobrachys hardwickei* (Pocock,1896)		Panda et al. 2011	#, E_I
15	*Chilobrachys* sp.	WILD-16-ARA-1410, 1411	PS	#, F_3
16	*Heterophrictus* sp.	WILD-16-ARA-1406, 1407, 1413, 1467	PS	#, F_3, E_I
17	*Plesiophrictus* sp.		Gravely 1921; Siliwal & Molur 2008	
18	*Poecilotheria miranda* Pocock, 1900		Molur et al. 2008; Siliwal & Molur 2008; Siliwal et al. 2008	#, E_I, En
19	*Poecilotheria tigrinawesseli* Smith, 2006		Siliwal & Molur 2008	#, E_{SA}
ARANEOMORPHAE				
Family Agelenidae C.L. Koch, 1837 (Funnel web spiders)				
20	*Agelena* sp.	IPU-16-ARA-237	PS	#, F_3
Family Amaurobiidae Thorell, 1870 (Funnel web spiders)				
21	*Amaurobius* sp.		Gravely 1921	
Family Araneidae Clerck, 1757 (Orb web or tent web spiders)				
22	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)		Gravely 1921	
23	*Arachnura* sp.		Siliwal & Molur 2008	
24	*Araneus bilunifer* Pocock, 1900	IPU-16-ARA-189	Siliwal & Molur 2008; PS	#, E_I
25	*Araneus ellipticus* (Tikader & Bal, 1981)	IPU-17-ARA-318, 319	Panda et al. 2011; PS	#
26	*Araneus mitificus* (Simon, 1886)	IPU-16-ARA-250	Mohapatra et.al. 2014; PS	#
27	*Araneus viridisomus* Gravely, 1921		Gravely 1921; Biswas 1987	E_I
28	*Araniella cucurbitina* (Clerck, 1757)		Siliwal & Molur 2008	
29	*Argiope aemula* (Walckenaer, 1842)	IPU-16-ARA-108	Siliwal & Molur 2008; PS	#
30	*Argiope anasuja* Thorell, 1887	IPU-16-ARA-58, 349, 350; IPU-17-ARA-362	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014; PS	#

	Species	Catalogue no.	Reference	Remarks
31	*Argiope catenulata* (Doleschall, 1859)		Biswas 1987; Ramakrishna et al. 2006	#
32	*Argiope minuta* Karsch, 1879		Siliwal & Molur 2008	
33	*Argiope pulchella* Thorell, 1881	IPU-16-ARA-307	Tikader 1982; Biswas 1987; Ramakrishna et al. 2006; Panda et al. 2011; Mohapatra et al. 2014; PS	#
34	*Cyclosa bifida* Doleschall, 1859	IPU-16-ARA-211, 212	Panda et al. 2011; Mohapatra et al. 2014; PS	#
35	*Cyclosa confraga* (Thorell, 1892)		Siliwal & Molur 2008	
36	*Cyclosa hexatuberculata* Tikader, 1982	IPU-17-ARA-357	Siliwal & Molur 2008; PS	#, E_{SA}
37	*Cyclosa insulana* (Costa, 1834)		Gravely 1921; Biswas 1987; Siliwal & Molur 2008	
38	*Cyclosa* sp.	IPU-16-ARA-150, IPU-17-ARA-400	Siliwal & Molur 2008; PS	#
39	*Cyclosa spirifera* Simon, 1889		Siliwal & Molur 2008	E_{SA}
40	*Cyrtarachne* sp.		Siliwal & Molur 2008; Mohapatra et.al. 2014	
41	*Cyrtophora cicatrosa* (Stoliczka, 1869)		Gravely 1921; Biswas 1987; Siliwal & Molur 2008	
42	*Cyrtophora citricola* (Forskal, 1775)		Biswas 1987; Panda et al. 2011; Mohapatra et al. 2014	#
43	*Eriovixia excelsa* (Simon, 1889)	IPU-16-ARA-28	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Mohapatra et al. 2014; PS	#
44	*Eriovixia laglaizei* (Simon, 1877)	IPU-16-ARA-294	PS	#, F_3
45	*Eriovixia poonaensis* (Tikader & Bal, 1981)		Ramakrishna et al. 2006	#
46	*Gasteracantha geminata* (Fabricius, 1798)	IPU-16-ARA-185, 186	PS	#, F_3, E_{SA}
47	*Gasteracantha hasselti* C.L. Koch, 1837	IPU-16-ARA-204, IPU-16-ARA-205	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; PS	#
48	*Gasteracantha kuhli* C.L. Koch, 1837		Biswas 1987	
49	*Gasteracantha unguifera* Simon, 1889	IPU-17-ARA-325	Siliwal & Molur 2008; PS	#
50	*Gea spinipes* C.L. Koch, 1843	IPU-16-ARA-155	PS	#, F_3
51	*Herennia multipuncta* (Doleschall, 1859)		Siliwal & Molur 2008	
52	*Larinia phthisica* (L. Koch, 1871)		Biswas 1987; Mohapatra et.al. 2014	
53	*Neoscona bengalensis* Tikader & Bal, 1981		Mohapatra et al. 2014	E_{SA}
54	*Neoscona molemensis* Tikader & Bal, 1981		Biswas 1987	
55	*Neoscona mukerjei* Tikader, 1980	IPU-16-ARA-13, 94, 97; IPU-17-ARA-445	Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; PS	#, E_{SA}
56	*Neoscona nautica* (L. Koch, 1875)		Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014	#
57	*Neoscona* sp.	IPU-16-ARA-293	Siliwal & Molur 2008; PS	#
58	*Neoscona theisi* (Walckenaer, 1841)	IPU-16-ARA-80	Tikader 1982; Biswas 1987; PS	#
59	*Neoscona vigilans* (Blackwall, 1865)		Tikader 1982; Biswas 1987; Panda et al. 2011; Mohapatra et al. 2014	#
60	*Nephila kuhli* (Doleschall, 1859)	IPU-16-ARA-115	Panda et al. 2011; PS	#
61	*Nephila pilipes* (Fabricius, 1793)	IPU-16-ARA-257, 258, 259	Biswas 1987; Ramakrishna et al 2006; Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014; PS	#
62	*Parawixia dehaani* (Doleschall, 1859)		Panda et al. 2011; Mohapatra et al. 2014	#
63	*Phonognatha* sp.		Siliwal & Molur 2008	
64	*Plebs himalayaensis* (Tikader, 1975)	IPU-17-ARA-384, 385	PS	#, F_3, E_{SA}
65	*Poltys nagpurensis* Tikader, 1982	IPU-17-ARA-429	PS	#, F_3, E_I
66	*Thelacantha brevispina* (Doleschall, 1857)	IPU-16-ARA-116, 187	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; PS	#
Family Cheiracanthiidae Wagner, 1887 (Sac or tube spiders)				
67	*Cheiracanthium danieli* Tikader, 1975	IPU-17-ARA-417	Panda et al. 2011; Mohapatra et al. 2014; PS	#, E_I

	Species	Catalogue no.	Reference	Remarks
68	*Cheiracanthium melanostomum* (Thorell, 1895)		Biswas 1987; Majumder & Tikader 1991	
Family Cithaeronidae Simon, 1893 (Curly legged spiders)				
69	*Inthaeron* sp. (1)	IPU-16-ARA-111	PS	#, F_3, E_O
70	*Inthaeron* sp. (2)	IPU-17-ARA-388	PS	#, F_3, E_I
Family Clubionidae Wagner, 1887 (Sac or tube spiders)				
71	*Clubiona* sp.	IPU-16-ARA-225, 227	Siliwal & Molur 2008; PS	#
Family Corinnidae Karsch, 1880 (Antmimic spiders)				
72	*Castianeira zetes* Simon, 1897		Biswas 1987; Majumder & Tikader 1991; Mohapatra et al. 2014	E_{SA}
73	*Cambalida flavipes* (Gravely, 1931)		Biswas 1987; Majumder & Tikader 1991	EI
74	*Cambalida* sp.	IPU-17-ARA-395	PS	#, F_3
75	*Corinnomma* sp.		Gravely 1921	
Family Ctenidae Keyserling, 1877 (Wandering spiders)				
76	*Anahita smythiesi* (Simon, 1897)	IPU-16-ARA-89	PS	#, F_3, E_I
77	*Ctenus narashinhai* Patel & Reddy, 1988	IPU-16-ARA-241	PS	#, F_3, E_I
78	*Ctenus* sp.	IPU-16-ARA-134	PS	#, F_3
Family Dictynidae O. Pickard-Cambridge, 1871 (Mesh web spiders)				
79	*Dictyna* sp.		Gravely 1921	
80	*Nigma* sp.	IPU-16-ARA-179	PS	#, F_3
Family Eresidae C. L. Koch, 1845 (Velvet spiders)				
81	*Stegodyphus sarasinorum* Karsch, 1891	IPU-16-ARA-71, 72	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; PS	#
Family Filistatidae Ausserer, 1867 (Crevice weaver spiders)				
82	*Filistata* sp.		Gravely 1921	
Family Gnaphosidae Pocock, 1898 (Ground spiders)				
83	*Drassodes astrologus* (O. Pickard-Cambridge, 1874)	IPU-17-ARA-399, 413	PS	#, F_3, E_I
84	*Drassodes pashanensis* Tikader & Gajbe, 1977		Biswas 1987	E_I
85	*Gnaphosa pauriensis* Tikader & Gajbe, 1977		Biswas 1987	#, E_I
86	*Gnaphosa* sp.	IPU-17-ARA-366	PS	#, F_3
87	*Sosticus dherikanalensis* Gajbe, 1979		Gajbe 1979; Tikader 1982; Biswas 1987	#, E_O
88	*Sosticus sundargarhensis* Gajbe, 1979		Gajbe 1979; Tikader 1982; Biswas 1987	E_O
89	*Setaphis parvula* (Lucas, 1846)	IPU-16-ARA-15	PS	#, F_3
90	*Setaphis subtilis* (Simon, 1897)		Biswas 1987	
91	*Zelotes sataraensis* Tikader & Gajbe, 1979	IPU-17-ARA-398	PS	#, F_3, E_I
92	*Zelotes* sp.	IPU-17-ARA-378, 403	PS	#, F_3
Family Hersiliidae Thorell, 1870 (Two-tailed spiders)				
93	*Hersilia savignyi* Lucas, 1836	IPU-16-ARA-33, 48; IPU-17-ARA-420, 422	Gravely 1921; Biswas 1987; Ramakrishna et al. 2006; Panda et al. 2011; Mohapatra et al. 2014; PS	#
Family Liocranidae Simon, 1897 (Spiny-legged sac spiders)				
94	*Oedignatha microscutata* Reimoser, 1934		Majumder & Tikader 1991; Biswas 1987; Ramakrishna et al. 2006	#, E_I
95	*Oedignatha scrobiculata* Thorell, 1881		Gravely 1921; Biswas 1987; Majumder & Tikader 1991	
96	*Oedignatha* sp.	IPU-16-ARA-243, 282; IPU-17-ARA-390	Siliwal & Molur 2008; PS	#
97	*Sphingius barkudensis* Gravely, 1931		Biswas 1987; Gravely 1931; Majumder & Tikader 1991	E_{SA}
98	*Sphingius* sp.		Gravely 1921	

	Species	Catalogue no.	Reference	Remarks
Family Lycosidae Sundevall, 1833 (Wolf spiders)				
99	*Arctosa* sp.		Siliwal & Molur 2008	
100	*Draposa atropalpis* (Gravely, 1924)	IPU-16-ARA-106	Gravely 1924; Tikader & Malhotra 1980; Biswas 1987; PS	#, E_{SA}
101	*Draposa lyrivulva* (Bösenberg & Strand, 1906)		Gravely 1924; Tikader & Malhotra 1980; Biswas 1987	E_{SA}
102	*Draposa oakleyi* (Gravely, 1924)	IPU-16-ARA-135	PS	#, F_3
103	*Evippa* sp.	IPU-16-ARA-147	PS	#, F_3
104	*Hippasa agelenoides* (Simon,1884)		Panda et al. 2011; Mohapatra et al. 2014	#
105	*Hippasa greenalliae* (Blackwall, 1867)	IPU-16-ARA-158	Gravely 1921; Tikader & Malhotra 1980; Biswas 1987; Panda et al. 2011; PS	#, E_{SA}
106	*Hippasa* sp.	IPU-16-ARA-264	Siliwal & Molur 2008; PS	#
107	*Lycosa iranii* Pocock, 1901	IPU-17-ARA-424, 425	PS	#, F_3, E_I
108	*Lycosa mackenziei* Gravely, 1924		Panda et al. 2011	#, E_{SA}
109	*Lycosa madani* Pocock, 1901		Biswas 1987	E_I
110	*Lycosa prolifica* Pocock, 1901	IPU-16-ARA-50	PS	#, F_3, E_I
111	*Ocyale pilosa* (Roewer, 1960)		Biswas 1987; Tikader & Malhotra 1980	
112	*Pardosa birmanica* Simon, 1884		Tikader & Malhotra 1980; Biswas 1987; Panda et al. 2011	#
113	*Pardosa mukundi* Tikader & Malhotra, 1980	IPU-16-ARA-84	PS	#, F_3, E_I
114	*Pardosa pseudoannulata* (Bösenberg & Strand, 1906)		Mohapatra et al. 2014	
115	*Pardosa sumatrana* (Thorell, 1890)	IPU-16-ARA-110	PS	#, F_3
Family Mimetidae Simon, 1881 (Pirate spiders)				
116	*Mimetus* sp.	IPU-16-ARA-206	PS	#, F_3
Family Miturgidae Simon, 1886 (Prowling spiders)				
117	*Systaria barkudensis* (Gravely, 1931)		Gravely 1931; Biswas 1987	E_O
Family Oonopidae Simon, 1890 (Goblin spiders)				
118	*Brignolia* sp.	IPU-17-ARA-511, 513, 514	PS	#, F_3, E_O
119	*Gamasomorpha* sp.	IPU-17-ARA-324, 374, 375, 500	PS	#, F_3, E_O
120	*Pelicinus* sp.	IPU-17-ARA-512	PS	#, F_3, E_O
Family Oxyopidae Thorell, 1870 (Lynx spiders)				
121	*Hamadruas* sp.	IPU-16-ARA-6	PS	#, F_3
122	*Oxyopes bharatae* Gajbe, 1999	IPU-16-ARA-5, 24	PS	#, F_3, E_I
123	*Oxyopes birmanicus* Thorell, 1887		Panda et al. 2011; Mohapatra et al. 2014	#
124	*Oxyopes javanus* Thorell, 1887		Panda et al. 2011; Mohapatra et al. 2014	#
125	*Oxyopes shweta* Tikader, 1970	IPU-16-ARA-25	Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014; PS	#
126	*Oxyopes sunandae* Tikader, 1970		Panda et al. 2011	#, E_{SA}
127	*Peucetia harishankarensis* Biswas, 1975		Biswas 1975; Biswas 1987	#, E_O
128	*Peucetia* sp.	IPU-16-ARA-19, 230	Siliwal & Molur 2008; PS	#
129	*Peucetia viridana* (Stoliczka, 1869)		Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014	#
Family Palpimanidae Thorell, 1870 (Palp-footed spiders)				
130	*Sarascelis raffrayi* Simon, 1893		Gravely 1921	
Family Pholcidae C.L. Koch, 1850 (Cellar spiders)				
131	*Artema atlanta* Walckenaer, 1837		Gravely 1921; Biswas 1987	

	Species	Catalogue no.	Reference	Remarks
132	*Crossopriza lyoni* (Blackwall, 1867)	IPU-16-ARA-20, 88	Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014; PS	#
133	*Pholcus fragillimus* Strand, 1907	IPU-16-ARA-249, 272, 273	PS	#, F_3
134	*Pholcus* sp.	IPU-16-ARA-274	Siliwal & Molur 2008; PS	#
135	*Smeringopus* sp.		Gravely 1921	
Family Pisauridae Simon, 1890 (Nursery web spiders)				
136	*Dendrolycosa gitae* (Tikader, 1970)		Siliwal & Molur 2008	E_I
137	*Nilus albocinctus* (Doleschall, 1859)		Panda et al. 2011	#
138	*Perenethis venusta* L. Koch, 1878		Mohapatra et al. 2014	
Family Salticidae Blackwall, 1841 (Jumping spiders)				
139	*Bianor narmadaensis* (Tikader, 1975)		Biswas 1987; Ramakrishna et al. 2006	#, EI
140	*Bianor pashanensis* (Tikader, 1975)		Biswas 1987	#, E_I
141	*Carrhotus* sp.	IPU-17-ARA-402	PS	#, F_3
142	*Carrhotus viduus* (C.L. Koch, 1846)		Panda et al. 2011; Mohapatra et al. 2014	#
143	*Epeus* sp.		Panda et al. 2011	#
144	*Epocilla* sp.	IPU-16-ARA-196	PS	#, F_3
145	*Habrocestoides* sp.	IPU-17-ARA-372	PS	#, F_3, E_{SA}
146	*Harmochirus brachiatus* (Thorell, 1877)	IPU-16-ARA-59	PS	#, F_3
147	*Hasarius adansoni* (Audouin, 1826)	IPU-16-ARA-21	Mohapatra et al. 2014; PS	#
148	*Hyllus semicupreus* (Simon, 1885)	IPU-16-ARA-81, 148	Biswas 1987; Panda et al. 2011; Mohapatra et al. 2014; PS	#, E_{SA}
149	*Hyllus* sp.	IPU-16-ARA-203	PS	#, F_3
150	*Marpissa decorata* Tikader, 1974		Biswas 1987	#, E_I
151	*Menemerus bivittatus* (Dufour, 1831)	IPU-17-ARA-360	Panda et al. 2011; PS	#
152	*Menemerus fulvus* (L. Koch, 1878)	IPU-17-ARA-423	PS	#, F_3
153	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869)	IPU-16-ARA-218, 222	Biswas 1987; Mohapatra et al. 2014; PS	#
154	*Myrmarachne melanocephala* MacLeay, 1839		Panda et al. 2011; Mohapatra et al. 2014	#
155	*Myrmarachne ramunni* Narayan, 1915	IPU-17-ARA-356	PS	F_2, E_{SA}
156	*Myrmarachne* sp.	IPU-16-ARA-303	Siliwal & Molur 2008; PS	#
157	*Phidippus bengalensis* Tikader, 1977		Biswas 1987	E_I
158	*Phintella bifurcata* Prószyński, 1992	IPU-17-ARA-408	PS	#, F_3, E_I
159	*Phintella vittata* (C.L. Koch, 1846)	IPU-16-ARA-31, 32, 51, 87	Mohapatra et al. 2014; PS	#
160	*Phlegra dhakuriensis* (Tikader, 1974)		Biswas 1987	#, E_{SA}
161	*Plexippus paykulli* (Audouin, 1826)	IPU-16-ARA-8, 86; IPU-17-ARA-317	Biswas 1987; Ramakrishna et al. 2006; Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014; PS	#
162	*Plexippus petersi* (Karsch, 1878)		Panda et al. 2011; Mohapatra et al. 2014	#
163	*Portia* sp. (1)	IPU-16-ARA-219	PS	#, F_3
164	*Portia* sp. (2)	IPU-16-ARA-157	Gravely 1921; Siliwal & Molur 2008; PS	#
165	*Rhene danieli* Tikader, 1973		Biswas 1987; Panda et al. 2011	#, E_I
166	*Rhene indica* Tikader, 1973		Biswas 1987	
167	*Siler semiglaucus* Simon, 1901		Panda et al. 2011	#
168	*Stenaelurillus gabrieli* Prajapati et al., 2016	IPU-17-ARA-428	PS	#, F_3, E_I
169	*Stenaelurillus arambagensis* (Biswas & Biswas, 1992)	IPU-17-ARA-421	PS	#, F_3, E_I
170	*Stenaelurillus* sp.	IPU-16-ARA-82, 238	PS	#, F_3, E_I

	Species	Catalogue no.	Reference	Remarks
171	*Telamonia dimidiata* (Simon, 1899)	IPU-16-ARA-143	Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014; PS	#
172	*Thiania bhamoensis* Thorell, 1887		Biswas 1987	#
173	*Thyene imperialis* (Rossi, 1846)	IPU-16-ARA-99	PS	#, F_3
Family Scytodidae Blackwall, 1864 (Spitting spiders)				
174	*Scytodes pallida* Doleschall, 1859		Gravely 1921, Panda et al. 2011	#
175	*Scytodes thoracica* Latreille, 1802		Panda et al. 2011	#
Family Segestriidae Simon, 1893 (Tube-dwelling spiders)				
176	*Ariadna nebulosa* Simon, 1906		Gravely 1921	E_I
177	*Ariadna* sp. (1)	IPU-17-ARA-447, 448	PS	#, F_3, E_O
178	*Ariadna* sp. (2)	IPU-17-ARA-455, 456	PS	#, F_3, E_O
Family Selenopidae Simon, 1897 (Giant wall crab spiders)				
179	*Makdiops* sp.	IPU-17-ARA-430	PS	#, F_3, E_I
180	*Selenops radiatus* Latreille, 1819		Biswas 1987	
Family Sparassidae Bertkau, 1872 (Giant crab spiders)				
181	*Heteropoda hampsoni* Pocock, 1901	IPU-16-ARA-145	PS	#, F_3, E_I
182	*Heteropoda kandiana* Pocock, 1899		Biswas 1987	E_{SA}
183	*Heteropoda phasma* Simon, 1897	IPU-16-ARA-305, 312	PS	#, F_3, E_I
184	*Heteropoda sexpunctata* Simon, 1885	IPU-16-ARA-90	Gravely 1921; Biswas 1987; PS	#
185	*Heteropoda venatoria* (Linnaeus, 1767)		Gravely 1921; Siliwal & Molur 2008; Mohapatra et al. 2014; Panda et al. 2011	#
186	*Olios iranii* (Pocock, 1901)	IPU-16-ARA-301	PS	F_2
187	*Olios lamarcki* (Latreille, 1806)		Gravely 1921; Biswas 1987	
188	*Olios milleti* (Pocock, 1901)		Gravely 1931; Biswas 1987; Mohapatra et al. 2014; Panda et al. 2011	#, E_{SA}
189	*Olios punctipes* Simon, 1884		Biswas 1987	
190	*Olios* sp.	IPU-16-ARA-191	Siliwal & Molur 2008; PS	#
191	*Palystes flavidus* Simon, 1897		Gravely 1921; Biswas 1987	E_I
192	*Spariolenus tigris* Simon, 1880		Biswas 1987	#
Family Stenochilidae Thorell, 1873 (Diamond-headed. Spiders)				
193	*Stenochilus hobsoni* O. Pickard-Cambridge, 1871	IPU-16-ARA-575	PS	#, F_3, E_I
Family Tetragnathidae Menge, 1866 (Long jawed spiders)				
194	*Guizygiella melanocrania* (Thorell, 1887)		Gravely 1921; Biswas 1987	
195	*Guizygiella* sp.	IPU-17-ARA-329	Panda et al. 2011; Mohapatra et al. 2014; PS	#
196	*Leucauge celebesiana* (Walckenaer, 1841)		Biswas 1987	#
197	*Leucauge decorata* (Blackwall, 1864)	IPU-16-ARA-120	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Mohapatra et al. 2014; PS	#
198	*Leucauge* sp.	IPU-16-ARA-55	PS	#, F_3
199	*Leucauge tessellata* (Thorell, 1887)	IPU-16-ARA-121, 122	PS	#, F_3
200	*Opadometa fastigata* (Simon, 1877)		Gravely 1921; Biswas 1987; Siliwal & Molur 2008	
201	*Tetragnatha ceylonica* O. Pickard-Cambridge, 1869		Gravely 1921; Biswas 1987	
202	*Tetragnatha cochinensis* Gravely, 1921		Panda et al. 2011	#, E_I
203	*Tetragnatha hasselti* Thorell, 1890	IPU-17-ARA-336	PS	#, F_3
204	*Tetragnatha javana* (Thorell, 1890)		Biswas 1987	

	Species	Catalogue no.	Reference	Remarks
205	*Tetragnatha mandibulata* Walckenaer, 1841	IPU-16-ARA-129	Gravely 1921; Biswas 1987; Siliwal & Molur 2008; Panda et al. 2011; Mohapatra et al. 2014; PS	#
206	*Tetragnatha maxillosa* Thorell, 1895	IPU-16-ARA-193, 194	PS	#, F_3
207	*Tetragnatha* sp.	IPU-17-ARA-340, 341, 343	PS	#, F_3
208	*Tetragnatha viridorufa* Gravely, 1921		Gravely 1921; Biswas 1987	E_I
209	*Tylorida* sp.	IPU-16-ARA-126, 168	PS	#, F_3
Family Theridiidae Sundevall, 1833 (Comb-footed spiders)				
210	*Argyrodes argentatus* O. Pickard-Cambridge, 1880		Gravely 1921	
211	*Argyrodes scintillulanus* O. Pickard-Cambridge, 1880		Gravely 1921	E_{SA}
212	*Argyrodes* sp.	IPU-16-ARA-69, 91	Siliwal & Molur 2008; PS	#
213	*Episinus* sp.	IPU-17-ARA-434	PS	#, F_3
214	*Meotipa andamanensis* (Tikader, 1977)		Mohapatra et al. 2014;	E_I
215	*Nihonhimea mundula* (L. Koch, 1872)	IPU-16-ARA-66	Siliwal & Molur 2008; Panda et al. 2011; PS	#
216	*Parasteatoda kompirensis* (Bösenberg & Strand, 1906)	IPU-16-ARA-271	PS	#, F_1, F_3
217	*Parasteatoda* sp. (2)	IPU-16-ARA-138	Siliwal & Molur 2008; PS	#
218	*Parasteatoda* sp. (3)	IPU-16-ARA-235, 236	PS	#, F_3
219	*Rhomphaea* sp.	IPU-17-ARA-335	Gravely 1921; PS	#
220	*Steatoda* sp. (1)	IPU-16-ARA-215	PS	#, F_3
221	*Steatoda* sp. (2)	IPU-16-ARA-236, IPU-17-ARA-370	PS	#, F_3
222	*Theridion* sp.	IPU-17-ARA-469, IPU-16-ARA-36	Siliwal & Molur 2008; PS	#
Family Thomisidae Sundevall, 1833 (Crab spiders)				
223	*Amyciaea forticeps* (O. Pickard-Cambridge, 1873)	IPU-16-ARA-112	PS	#, F_3
224	*Amyciaea* sp.	IPU-16-ARA-23	PS	#, F_3
225	*Bomis* sp.	IPU-16-ARA-27	PS	#, F_3
226	*Camaricus formosus* Thorell, 1887		Panda et al. 2011; Mohapatra et al. 2014	#
227	*Camaricus khandalaensis* Tikader, 1980		Panda et al. 2011; Mohapatra et al. 2014	#, E_I, F_3
228	*Camaricus* sp.	IPU-16-ARA-109	PS	#, F_3
229	*Indoxysticus minutus* (Tikader, 1960)		Mohapatra et al. 2014	E_{SA}
230	*Indoxysticus* sp.	IPU-17-ARA-401, 439	PS	#, F_3
231	*Oxytate* sp.	IPU-16-ARA-76	PS	#, F_3
232	*Runcinia* sp.	IPU-16-ARA-181	PS	#, F_3
233	*Thomisus lobosus* Tikader, 1965		Mohapatra et al. 2014	E_I
234	*Thomisus projectus* Tikader, 1960		Mohapatra et al. 2014	E_I
235	*Thomisus pugilis* Stoliczka, 1869		Panda et al. 2011	#, E_I
236	*Thomisus sikkimensis* Tikader, 1962		Panda et al. 2011	#, E_I
237	*Thomisus* sp.	IPU-16-ARA-74	Siliwal & Molur 2008; PS	#
Family Titanoecidae Lehtinen, 1967 (Rock weaver spiders)				
238	*Pandava laminata* (Thorell, 1878)	IPU-16-ARA-139, 244, 361	PS	#, F_3
Family Uloboridae Thorell, 1869 (Feather-legged lace weavers)				
239	*Uloborus* sp.	IPU-16-ARA-118, 119	Gravely 1921; Mohapatra et al. 2014; PS	#
240	*Zosis geniculata* (Olivier, 1789).	IPU-16-ARA-224	PS	#, F_3

	Species	Catalogue no.	Reference	Remarks
Family Zodariidae Thorell, 1881 (Ant spiders)				
241	*Asceua cingulata* (Simon, 1905)		Gravely 1921; Biswas 1987	E_I
242	*Asceua* sp.	IPU-17-ARA-353, 354	PS	#, F_3
243	*Hermippus arjuna* (Gravely, 1921)		Gravely 1921; Biswas 1987; Siliwal & Molur 2008	E_I
244	*Hermippus* sp.	IPU-16-ARA-286	Panda et al. 2011; PS	#
245	*Mallinella* sp.	IPU-16-ARA-103, 173, 280	PS	#, F_3
246	*Storena birenifer* Gravely, 1921		Gravely 1921; Biswas 1987; Siliwal & Molur 2008	E_O
247	*Storena* sp.		Gravely 1921	
248	*Suffasia* sp.	IPU-16-ARA-162	PS	#, F_3

Note: PS - Present Study | # - Report from Eastern Ghats of Odisha | F_1 - First report from India | F_2 - First report from Odisha (outside Eastern Ghats portion of Odisha) | F_3 - First report from Odisha (within Eastern Ghats portion of Odisha) | E_{SA} - Endemic to South Asia | E_I - Endemic to India | E_O - Reported from Odisha State only | En - Endangered | IPU - Indraprastha University | WILD - Wildlife Information Liaison Development Society.

Image 1. A - *Conothele varvarti* | B - *Araneus mitificus* | C - *Gasteracantha geminata* | D - *Argiope anasuja* | E - *Nephila pilipes* | F - *Thelacantha brevispina*.

Image 1. G - *Hersilia savignyi* | H - *Oxyopes bharatae* | I - *Peucetia viridana* | J - *Myrmaplata plataleoides* | K - *Stenaelurillus arambagensis* | L - *Stenochilus hobsoni*.

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Status of water birds in Haripura-Baur Reservoir, western Terai-Arc landscape, Uttarakhand, India

Tanveer Ahmed [1], Harendra Singh Bargali [2], Deepa Bisht [3], Gajendra Singh Mehra [4] & Afifullah Khan [5]

[1,2,3,4] The Corbett Foundation, Village & P.O. Dhikuli, Ramnagar, Uttarakhand 244715, India.
[1,5] Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.
[1] tanveerwildlife@gmail.com, [2] harendratcf@gmail.com (corresponding author), [3] deepa_ocean1981@yahoo.co.in, [4] gajendra.singh.skd@gmail.com, [5] afifullah.khan@gmail.com

Abstract: We surveyed water birds in Haripura-Baur Reservoir using total count method between 2013 and 2015. A total of 65 species were recorded representing eight orders and 14 families. Numerically Anatidae was the dominant family followed by Ardeidae and Scolopacidae. Common Coot *Fulica atra*, Red-crested Pochard *Netta rufina*, Common Pochard *Aythya ferina*, Gadwall *Anas strepera*, and Tufted Pochard *Aythya fuligula* were dominant species in the reservoir. The Shannon diversity of water birds was more or less consistent over the years and ranged between 2.56 (2013–14) and 2.23 (2015–16). The reservoir supports water birds having declining population trends globally (41% of species), including three Vulnerable (Asian Woollyneck *Ciconia episcopus*, Lesser Adjutant *Leptoptilos javanicus*, and Sarus Crane *Grus antigone* and four Near Threatened species (Oriental Darter *Anhinga melanogaster*, Painted Stork *Mycteria leucocephala*, Black-necked Stork *Ephippiorhynchus asiaticus,* and River Lapwing *Vanellus duvaucelii*). Bird species belong to four feeding guilds with the domination of the carnivore group. The current information is expected to serve as preliminary database of water birds for further research and monitoring.

Keywords: Bird community, diversity, freshwater, guild, richness, wetland.

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Author details: Tanveer Ahmed is PhD student in Department of Wildlife Sciences, AMU. He has experience of working on birds and mammals of Ladakh and preparing management plans. Dr. Harendra Singh Bargali, Deputy Director at The Corbett Foundation (TCF), has been involved in conceptualising and supervising various conservation oriented research projects at grassroots level in Terai-Arc Landscape for more than 12 years. Dr. Deepa Bisht is currently working on validation and documentation of aromatic plants of Kumaon Himalaya. Her area of expertise encompasses antifungal efficacy of various essential oils isolated from aromatic plants of high altitude regions against grain storage fungi. Gajendra Singh Mehra holds a masters degree in Entomology from Kumaun University and a MPhil in herpetology. Dr. Afifullah Khan is chairman in the Department of Wildlife Sciences, AMU. He has served as member on several important committees constituted by the Ministry of Environment & Forests, Government of India and WWF-India.

Author contribution: TA analysed the data and wrote the manuscript. HSB conceptualized the study and was part of data collection process. DB and GSM were also involved in data collection. AK supervised the data collection and analysis.

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INTRODUCTION

Terai-Arc Landscape (henceforth TAL)—a green belt, runs along the foothills of the Himalaya from the river Bagmati in the east to the Yamuna in the west. It represents two distinct zones, i.e., Bhabar tract and the Terai plains of India (Rodgers & Panwar 1988). TAL is a mosaic of various habitats such as forests, grasslands, riverbeds, swamps, plantations, scrubland and wetlands that sustains birds representing Himalayan and Gangetic plain affinities (Rahmani et al. 1989; Pandey et al. 1994; Javed et al. 1999; Naoroji 1999; Dhakate et al. 2008).

The wetlands in the western part of TAL serve as an important habitat for resident and migratory birds (Dhakate et al. 2008; Bhattacharjee & Bargali 2013). Additionally, bird species categorized under the various categories of IUCN Red List of Threatened Species, viz., Darter *Anhinga melanogaster*, Painted Stork *Mycteria leucocephala*, Black-necked Stork *Ephippiorhynchus asiaticus*, Lesser Adjutant *Leptostilos javanicus*, Sarus Crane *Grus antigone*, and River Tern *Sterna aurantia* find home in these water bodies. Near Threatened migratory bird species such as Black-tailed Godwit *Limosa limosa* and Ferruginous Duck *Aythya nyroca* regularly winter in these wetlands (Bhattacharjee & Bargali 2013; Bhatt et al. 2014). Most importantly, the Bean Goose *Anser fabalis*, vagrant bird species which breed in the high Arctic and winter in temperate and sub-tropical regions (BirdLife International 2016) have been reported from these wetlands (Bhattacharjee 2013). The occurrence of these species highlight the significance of such wetlands for conservation of water birds, however, these water bodies do not have any legal conservation status and are basically managed for irrigation purposes. Furthermore, these wetlands are used for commercial fishing which not only reduces food availability to many native fish and bird species but is also a major cause of disturbance to the water birds.

Water birds assemblage in western TAL has been reported from Tumariya Reservoir (Bhattacharjee & Bargali 2013), Bheemgora barrage (Bhatt et al. 2014), Hathnikund barrage (Tak et al. 2010), and the water bodies of Corbett landscape (Dhakate et al. 2008). Information on the status of the water bird assemblage of Haripura-Baur Reservoir is not known and the present study is a pioneer attempt towards systematic data collection on water bird assemblage here. It is expected that the information will serve as a preliminary database of water birds for further research, monitoring and management.

MATERIALS AND METHODS

Study area

Haripura-Baur Reservoir (HBR) (29.135^{0}N & 79.294^{0}E) are earthen embankment dams located approximately 15km from Bazpur in Udham Singh Nagar District of Uttarakhand (Fig. 1; Image 1). HBR is a man-made wetland constructed in 1974 primarily for the purpose of storing water for irrigation purposes. Haripura having a maximum height of approximately 17m and length of 10km is built on Baur and Kakrala rivers, whereas, Baur with a maximum height of about 11m and length of 8km is built on Bhakhara River. Both reservoirs are adjacent to each other and spread over an area of 294.4km^2. Considering the limited height and primary role of providing water for irrigation these dams are rarely filled with water to the maximum capacity leaving shallow water areas towards the margins. Mostly the reservoir is devoid of any vegetation; however, the shallow water level at the eastern, western and northern periphery of HBR support aquatic free floating, submerged and semi-submerged plants such as *Ipomoea aquatica*, *Saccharum spontaneum*, *Typha* sp., *Polygonum barbatum*, *Vallisnaria* spp., *Hygrophila polysperma, Sagittaria sagittifolia, Phragmites karka*, *Azolla pinneta, Eichhornia crassipes, Nymphaea* spp., *Nymphoides cristata*, and *Stellaria media*. The southern edge of these dams is earthen embankment with a motorable road. Some introduced fish fauna in the reservoir includes *Catla catla* (Catla), *Labeo rohita* (Rohu), *Sperata seenghala, Hypophthalmichthys molitrix* (Silver Carp), *Cirrhinus mrigala* (Nain), *Channa marulius* (Saur), *C. striatus* (Shaul), and *Wallago attu* (Lachi).

Methods

Information on water birds was collected by visiting the wetland fortnightly during November–February (winter season) between 2013–14 and 2015–16. Birds were counted by applying total count method following Koskimies & Vaisanen (1991). Since it was not possible to cover the entire reservoir from a single point, water birds were counted by selecting more than one point. Species were recorded along with their numbers between 07.00h and 12.00h. Field observation were not carried out during adverse environment condition. Identification of species was based on Grimmett et al. (1998). Conservation status and global population trend of water birds in HBR was determined from IUCN (2016).

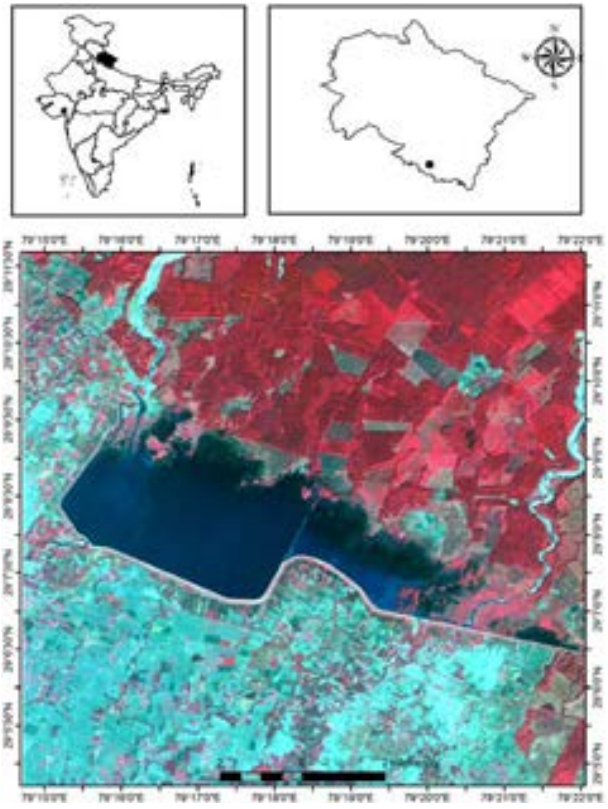

Figure 1. Haripura-Baur Reservoir in Uttarakhand, India.

Data analysis

Water bird community structure was determined through calculating various metrics such as Shannon's diversity (H), Margalef's richness (S), and evenness. Species richness represents totally unique species of water birds detected in all surveys. Shannon's diversity index describes diversity of species taking into account abundance of species. Evenness is an index of distribution of individuals among species. All the bird community indices were evaluated using Past 3.0 software (Hammer et al. 2017).

Maximum individuals of a bird species in a year were considered to determine the abundance of a species over a year. All the individuals of water birds sighted during various years were pooled to determine the abundance of bird species and birds were ranked into categories following Sultana & Khan (2000): Rare = 1–10 individuals; Common= 11–100 individuals; Abundant = 101–500 individuals; Very abundant = >500 individuals.

The mean rank abundance score for each species was calculated to assess the overall abundance in HBR. Birds were categorised into various feeding guilds following Ali (2002).

Image 1. Haripura-Baur Reservoir, Udham Singh Nagar District, Uttarakhand. © Harendra Singh Bargali.

RESULTS

A total of 65 species of water birds belonging to eight orders and 14 families were recorded in HBR. Of the recorded species, 36 species (55%) were resident, and 29 species (45%) were winter visitors. Among families, Anatidae was the dominant family with the maximum number of species (15 species) followed by Ardeidae (11 species), Scolopacidae and Ciconiidae (6 species each). Gruidae was the least represented family with only one species (Fig. 2). HBR support three Vulnerable species, viz., Woolly-necked Stork, Lesser Adjutant & Sarus Crane, and four Near Threatened species, viz., Darter, Painted Stork, Black-necked Stork & River Lapwing.

The Shannon diversity of water birds was more or less consistent over the years. It was 2.56, 2.45, and 2.23 during the year 2013–14, 2014–15, and 2015–16 respectively. Abundance of water birds was maximum (n=18,134 birds) during 2014–15 and minimum (n=8,452 birds) during 2013–14 (Table 1). Numerically, Common Coot (2,320–6,527 individuals), Red-crested Pochard (1,349–3,413 individuals), Common Pochard (937–2,692 individuals), Gadwall (942–1,099 individuals), and Tufted Pochard (527–1,191 individuals) were very abundant in the reservoir (Table 2). Species such as Oriental Darter (1–1), Painted Stork (9–10), Asian Woollyneck (5–11), Black-necked Stork (1–4), Lesser Adjutant (1), Sarus Crane (4–8), and River Lapwing (4–22) were rare in the reservoir. The reservoir supports a high proportion of water birds (41%) having a declining population trend globally (Fig. 3, Table 2).

Table 1. Status of birds in Haripura-Baur Reservoir, Uttarakhand, India.

Year	No. of species	Total individuals	Diversity	Richness	Evenness
2013–14	50	8452	2.52	5.41	0.24
2014–15	58	18134	2.45	5.71	0.20
2015–16	49	18098	2.23	4.89	0.19

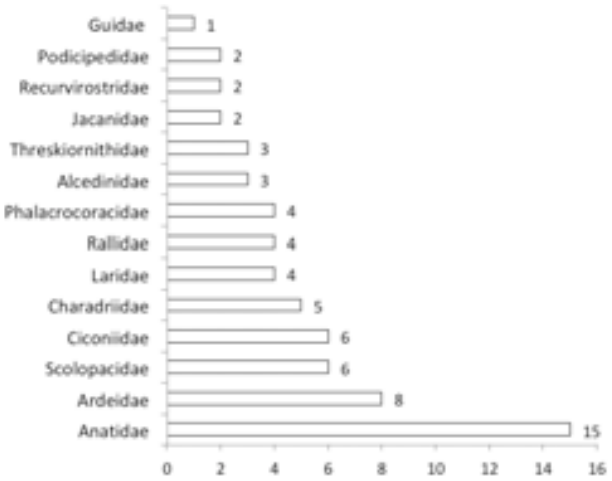

Figure 2. Species under various families in Haripura-Baur Reservoir, Uttarakhand, India.

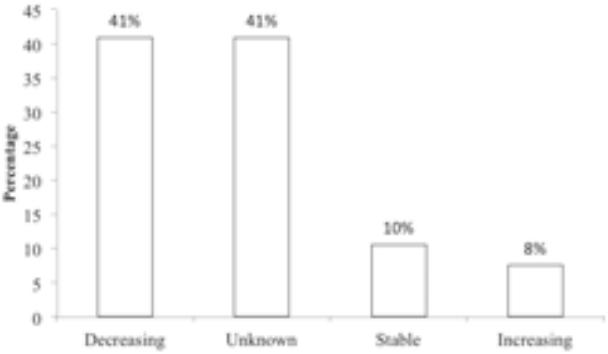

Figure 3. Global population trend of water bird species occurring in Haripura-Baur Reservoir, Uttarakhand, India.

Classification of observed species among feeding guilds revealed that the reservoirs support water birds belonging to four dietary guilds (Table 3). The carnivore guild was the dominant with maximum diversity (H=2.387) and richness (S=4.347). This guild was followed by omnivores (H=1.857, S=1.364). Insectivore birds were found least diverse and rich (H=0.928, S=0.73).

DISCUSSION

The wetlands in western TAL has been a regular winter abode for a large number of resident and migratory water birds (Dhakate et al. 2008; Bhattacharjee & Bargali 2013). HBR constructed primarily for the purpose of regulating water for irrigation purposes also supports water birds; however, there has been less focus on water birds visiting the reservoirs and on their conservation or management. The species recorded suggest that HBR support almost 50% of water birds species recorded from western TAL (Dhakate et al. 2008), and 23% of water bird species reported from India (Gopi et al. 2014). Almost half of the species recorded in HBR were migratory. Bhattacharjee & Bargali (2013) and Dhakate et al. (2008) found a similar proportion of migrant species in the wetlands of western TAL.

Family Anatidae was dominant in HBR. Studies conducted in wetland ecosystem in western TAL also advocated the dominancy of Anatidae (Dhakate et al. 2008; Kumar & Gupta 2009; Tak et al. 2010; Bhattacharjee

Table 2. Status and abundance of water birds in Haripura-Baur Reservoir, Uttarakhand, India.

Family	Species	Status	Global population trend	IUCN	Abundance 2013	Abundance 2014	Abundance 2015	Mean abundance Score
Podicipedidae	Little Grebe *Tachybaptus ruficollis*	R	D	LC	50	68	81	2
	Great Crested Grebe *Podiceps cristatus*	WV	UN	LC	143	542	466	3
Phalacrocoracidae	Great Cormorant *Phalacrocorax carbo*	R	IN	LC	12	74	56	2
	Little Cormorant *Phalacrocorax niger*	R	UN	LC	236	359	224	3
	Indian Cormorant *Phalacrocorax fuscicollis*	R	UN	LC	0	0	5	1
	Oriental Darter *Anhinga melanogaster*	R	D	NT	1	1	1	1
Ardeidae	Indian Pond Heron *Ardeola grayii*	R	UN	LC	8	9	15	1
	Purple Heron *Ardea purpurea*	R	D	LC	5	7	3	1
	Grey Heron *Ardea cinera*	R	UN	LC	8	14	7	1.
	Cattle Egret *Bubulcus ibis*	R	IN	LC	88	26	195	2
	Little Egret *Egretta garzetta*	R	IN	LC	54	83	69	2
	Intermediate Egret *Mesophoy xintermedia*	R	D	LC	37	54	30	1
	Great Egret *Casmerodius albus*	R	UN	LC	2	0	4	2
	Yellow Bittern *Ixobrychus sinensis*	R	UN	LC	0	0	1	1
Ciconiidae	Painted Stork *Mycteria leucocephala*	R	D	NT	0	10	9	1
	Asian Openbill *Anas oscitans*	R	UN	LC	94	53	169	2
	Black Stork *Ciconia nigra*	WV	UN	LC	0	5	2	1
	Asian Woollyneck *Ciconia episcopus*	R	D	VU	5	9	11	1
	Black-necked Stork *Ephippiorhynchus asiaticus*	R	D	NT	0	1	4	1
	Lesser Adjutant *Leptotilos javanicus*	R	D	VU	0	1	0	1
Threskiornithidae	Red-naped Ibis *Pseudibis papilosa*	R	D	LC	84	36	46	2
	Glossy Ibis *Plegadis falcinellus*	R	D	LC	20	12	0	2
	Eurasian Spoonbill *Platalea leucorodia*	R	UN	LC	2	0	0	1
Anatidae	Lesser-whistling Duck *Dendrocygna javanicus*	R	D	LC	0	12	0	1
	Graylag Goose *Anser anser*	WV	IN	LC	72	2	7	1
	Bar-headed Goose *Anser indicus*	WV	D	LC	28	12	34	2
	Ruddy Shelduck *Tadorna ferruginea*	WV	UN	LC	171	760	50	3
	Cotton Pygmy-goose *Nettapus coromandelianus*	R	ST	LC	62	137	1052	3
	Mallard *Anas platyrhynchos*	WV	D	LC	74	22	387	2
	Indian Spot-bill Duck *Anas poecilorhyncha*	R	D	LC	28	181	47	2
	Northern Pintail *Anas acuta*	WV	D	LC	355	380	1145	3
	Garganey *Anas querqueduedula*	WV	D	LC	5	0	0	1
	Northern Shoveler *Anas clypeata*	WV	D	LC	12	128	2	2
	Common Pochard *Aythya ferina*	WV	UN	LC	937	2692	1535	4
	Ferruginous Pochard *Aythya nyroca*	WV	D	LC	91	1021	103	3
	Red-crested Pochard *Netta rufina*	WV	UN	LC	1349	3011	3413	4
	Tufted Duck *Aythya fuligula*	WV	ST	LC	527	1191	661	4
	Gadwall *Anas strepera*	WV	UN	LC	969	942	1099	4
	Eurasian Wigeon *Mareca penelope*	WV	D	LC	95	46	97	2

Family	Species	Status	Global population trend	IUCN	Abundance 2013	Abundance 2014	Abundance 2015	Mean abundance Score
Gruidae	Sarus Crane *Grus antigone*	R	D	VU	4	8	0	1
Rallidae	White-breasted Waterhen *Amaurornis phoenicurus*	R	UN	LC	2	42	0	1
	Common Moorhen *Gallinula chloropus*	R	ST	LC	192	90	131	3
	Purple Swamphen *Porphyrio porphyrio*	R	UN	LC	29	96	66	3
	Common Coot *Fulica atra*	R	D	LC	2320	4782	6527	4
Jacanidae	Pheasant-tailed Jacana *Hydrophasianus chirurgus*	R	D	LC	27	40	48	2
	Bronze-winged Jacana *Metopidicus indicus*	R	UN	LC	15	27	27	2
Recurvirostridae	Black-winged Stilt *Himantopus himantopus*	R	IN	LC	0	9	9	1
	Pied Avocet *Recurvirostra avosetta*	WV	UN	LC	0	2	0	1
Charadriidae	Red-wattled Lapwing *Venellus indicus*	R	UN	LC	22	0	0	1
	Northern Lapwing *Venellus venellus*	WV	D	LC	0	2	0	1
	River Lapwing *Venellus duvacelii*	WV	UN	NT	4	22	6	1
	White-tailed Lapwing *Venellus leucurus*	WV	UN	LC	0	2	0	1
Scolopacidae	Common Redshank *Tringa totanus*	WV	UN	LC	6	20	0	1
	Common Greenshank *Tringa nebularia*	WV	ST	LC	0	5	0	1
	Wood Sandpiper *Tringa grareola*	WV	ST	LC	0	1	0	1
	Green Sandpiper *Tringa ochropus*	WV	ST	LC	0	2	9	1
	Common Sandpiper *Actitis hypoleucos*	WV	D	LC	2	7	0	1
	Pintail Snipe *Gallinago sternura*	WV	UN	LC	0	0	12	1
Laridae	Pallas' Gull *Ichthyaetus ichthyaetus*	WV	D	LC	17	46	2	2
	Brown-headed Gull *Chroicocephalus brunnicephalus*	WV	ST	LC	34	129	50	2
	Black-headed Gull *Chroicocephalus ridibundus*	WV	D	LC	140	58	164	3
Alcedinidae	Common Kingfisher *Alcedo atthis*	R	UN	LC	3	5	5	1
	White-breasted Kingfisher *Halcyon smyrnensis*	R	UN	LC	7	19	9	1
	Pied Kingfisher *Ceryle rudis*	R	UN	LC	3	9	3	1

Status: R—Resident, WV—Winter visitor; **Population trend:** D—Declining, IN—Increasing, ST—Stable, UN—Unknown; **Mean abundance score:** 1—Rare, 2—Common, 3—Abundant, 4—Very abundant; **IUCN:** LC—Least Concern | NT—Near Threatened | VU—Vulnerable.

& Bargali 2013). The occurrence of winter migrants and birds categorized under the IUCN Red List of Threatened Species signifies the importance of HBR as a foraging and resting habitat for migratory and resident water birds.

HBR supported a consistent diversity of water birds over the study period. The diversity of water birds recorded during the present study might be due to availability of a wide spectrum of feeding resources in the study area in the form of crustaceans, invertebrates, emergent vegetation and plankton. Moreover, occurrence of fish species like *Catla catla, Labeo rohita, Sperata seenghala*, and *Wallago attu* in the reservoir also serve as important dietary resources for water birds, as also the surrounding agriculture fields that provide foraging grounds. Kloskokowski et al. (2010) suggested fish age and biomass, amphibian abundance, water transparency and emergent vegetation govern the richness of water birds. The domination of carnivore guild in the reservoir could be due to the high availability of fish fauna. The low abundance of water birds during 2014–15 could be related to low water levels and subsequent agriculture-based activities in non-submerged areas. This also supports the results of Bolduc & Aftan (2008), who has highlighted that the water bird abundance is controlled by water depth.

Since the reservoir is managed by the irrigation

Image 2a–d. a—Great-crested Grebe | b—Common Coot | c—Brown-headed Gull; d—Red-crested Pochard. © Harendra Singh Bargali.

Table 3. Richness and diversity of birds under various feeding guild in Haripura-Baur Reservoir, Uttarakhand, India.

Index	Carnivore	Herbivore	Insectivore	Omnivore
Total species	37	10	4	14
Shannon diversity (H)	2.387	1.31	0.928	1.857
Margalef richness (S)	4.347	0.8822	0.7388	1.364
Evenness	0.2941	0.3707	0.6324	0.4574

department, there is a regular practice of commercial fishing to private parties for a stipulated time period. Fishing in the reservoir post monsoon causes lots of disturbance to the water birds. Hence, we strongly recommend to allow only traditional fishing activities through proper inter-departmental cooperation and for developing a sound policy to regulate water for irrigation purposes, commercial fishing with an emphasis on the conservation of water birds. Aarif et al. (2017) highlighted that traditional fishing activities enhance water bird abundance and diversity. Considering the limited water bodies in western TAL, HBR plays a considerable role in providing the required habitat to migratory as well as resident water birds. It provides home to a high proportion of water birds having declining population trends. If managed properly it will not only provide crucial habitat to water birds but an opportunity for promoting eco-tourism by developing the site as a bird tourism destination.

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PLATINUM OPEN ACCESS

Bird diversity in the coastal talukas of Sindhudurg District, Maharashtra, India

Golusu Babu Rao [1], Santhanakrishnan Babu [2], Goldin Quadros [3] & Vijaykumar Anoop [4]

[1,2,3,4] Sálim Ali Centre for Ornithology and Natural History, Anaikatty, Coimbatore, Tamil Nadu 641108, India.
[1] Manipal Academy of Higher Education, Madhav Nagar, Manipal, Karnataka 576104, India.
[1] rao.3in@gmail.com, [2] sanbabs@gmail.com (corresponding author), [3] goldinq@gmail.com, [4] pvanoop1@gmail.com

Abstract: The list of birds of Sindhudurg coastal district was compiled based on primary and secondary information. All observations were made along the Sindhudurg coast, i.e., from Terekhol to Vijaydurg. Wetland birds were recorded during sampling while terrestrial birds were recorded opportunistically. Besides, we also collated bird occurrence records from published literature (including grey literature and online resources) to prepare a comprehensive list of birds for Sindhudurg coast. During our study, we recorded 283 species, and 24 more species were compiled from secondary sources. Altogether, 307 species belonging to 78 families and 22 orders were recorded from the Sindhudurg coast. Order Passeriformes was dominant with 111 species. Among the 307 species, four species are endemic to the Western Ghats. Three species of vultures had been reported earlier but two were not encountered in recent years. Great Knot (EN), Woolly-necked Stork (VU) and 14 other species (NT) fall under various threat categories of IUCN. Species richness was higher in Vengurla (256) followed by Malvan (247) and Devgad talukas. Construction of homestays, unregulated tourism in coastal areas, and conversion of natural habitats to meet increasing tourism are the major threats to the coastal avifauna of the district. A high species richness of birds in Sindhudurg coast is attributed to the availability of a wide array of habitats (coastal to woodlands with different degrees of anthropogenic disturbances). Considering the high species richness of birds and livelihood dependency of humans on the coastal zones, a few estuaries namely Mochemad, Karli and Mitbav estuaries may be recognized as community/ conservation reserve to manage the ecosystem sustainably for long-term conservation of these estuaries and sub-habitats therein. Also, those sites can be perceived as Important Bird and Biodiversity Areas of IBCN as they fulfill the IBA criteria.

Keywords: Avifauna, conservation, laterite grasslands, Sindhudurg, Vengurla rocks.

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Author details: Golusu Babu Rao - my passion for wildlife is observing birds and understanding their behaviour in its natural environment. I am also interested in studying habitat use patterns of birds in changing landscape. Santhanakrishnan Babu - my research focuses on ornithology, landscape ecology, and Remote Sensing & GIS. Goldin Quadros - I am interested in the benthic invertebrates from wetland ecosystems. Anoop Vijay Kumar - my research involves different taxa such as birds and mammals and I have a special interest on Environmental Impact Assessment works.

Author contribution: SB, GBR and GQ conceived and designed the manuscript. GBR and AV conducted field surveys and data collection. GBR, AV and SB led the writing of the manuscript with inputs from GQ. All the authors equally contributed in refining the manuscript drafts and approved the final version.

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INTRODUCTION

Sindhudurg District is located geographically on the southwestern side of the state of Maharashtra and recognised as one of the principal tourist destinations in the western coast of India. The increasing inflow of tourists to Sindhudurg coast and subsequent change in land use and land cover of the coastal area increase the pressure on coastal and marine biodiversity. Due to its potential for over-exploitation of coastal biodiversity, MoEF&CC and the Maharashtra Forest Department – Mangrove Cell in collaboration with UNDP and GEF have initiated the Sindhudurg project to mainstream coastal biodiversity into a production sector. As part of the program, we compiled primary and secondary bird occurrence data along the Sindhudurg coasts to signify bird diversity wealth and to identify crucial bird areas for the conservation of coastal birds.

Southwestern Maharashtra (Ratnagiri and Sindhudurg) received much attention for bird studies from both the early-time British ornithologists and post-independence workers. Studies in Sindhudurg District can broadly be grouped into three categories based on the extent of focal area and target birds, viz., Sindhudurg District as a landscape level (Vidal 1980; Gole 1994; Prasad 2006; Mahabal et al. 2011), small regions or localities level (Hume 1876; Abdulali 1940, 1942, 1983; Madsen 1988; Pande 2002a; Lainer 2003; Katdare et al. 2004a; Patil 2015) and single or small group of birds level (Katdare 2001; Pande 2001, 2002b; Pande et al. 2001; Katdare et al. 2004b; Mahabal et al. 2007; Kambale et al. 2011; Rao et al. 2015). Vidal (1880) prepared the first comprehensive checklist on the birds of the Konkan region that included Sindhudurg District. Prasad (2006) included the Sindhudurg coast in his book on birds of western Maharashtra, though he did not specifically cover their local status. Studies by Khot (2016) included Malvan and Malagaon-Bagayat from Sindhudurg District but did not cover large parts of coastal zones in the Sindhudurg District. Patil et al. (2015) published a checklist for a single wetland (Pat Lake) in the district.

Considering this information and significance of the Sindhudurg coast, we have attempted to assess the local status, habitat association, sighting frequency and taluka-wise distribution of birds from the coastal talukas of Sindhudurg District based on primary and secondary observations from this region.

STUDY AREA

Sindhudurg District (15.37–16.40 ^{0}N & 73.19–74.18 ^{0}E) is located geographically on southwestern Maharashtra, and it was carved out from the erstwhile Ratnagiri District in 1981. The terrain is mostly gentlly undulating, and the elevation ranges from sea level to 120m. The state of Goa borders it in the south, Ratnagiri District in the north, Kolhapur District in the east and the Arabian Sea in the west (Fig. 1). Out of eight talukas, Vengurla, Malvan, and Devgad are coastal talukas. Coastal stretches of the district hold a wide-array of natural habitats, viz., sandy intertidal mudflats, mangroves, sandy beaches, rocky shoreline, and wooded forests. The coasts of Malvan Taluka has been recognized as Malvan Marine Wildlife Sanctuary in 1987. In addition to the coastal areas, we also did a survey at Pat Lake (freshwater lake), laterite grasslands (Chipi, Tondavali, Vengurla and other small grasslands), woodland areas within this buffer (moist deciduous forests and plantations), Vengurla rocks/islands (located nearly 6km from the coast), and man-modified sites (agriculture fields, saltpan and aquaculture ponds) (Images 1 & 2).

Pat Lake: Pat Lake is a freshwater lake located amid populated Pat Parule Village in Vengurla Taluka. This shallow lake with floating vegetation and mature trees on one side makes it a suitable habitat for several water-associated birds including ducks and geese. Agricultural fields and a road surround the lake.

Laterite grasslands: These grasslands were formed during the mid-tertiary period and are part of Deccan Trap floodplain (Seshadri et al. 2016). The overall habitat comprises grasses, herbs, shrubs and stunted trees interspersed with agricultural fields and habitation. Grasslands are found along the coastal areas of Sindhudurg District. Some of the meadows are extensive in size and, offer potential foraging ground for raptors (e.g., Harriers *Circus* sp.) and nesting ground for grassland birds (e.g., Lapwings *Vanellus* sp. and Larks *Alaudidae*). We selected Chipi, Tondavali, Vengurla and other small grasslands in these talukas for studying raptor and other grassland dependent birds.

Woodlands including plantations: Fragmented patches of moist deciduous forest and plantations (mango, coconut, cashew and *Casuarina*) are found in mosaics among the human settlements. The natural forests are not intact but possess dense upper-storey and mid-storey cover.

Vengurla rocks: It is a group of small rocky offshore islands located around six kilometres from the Kochara

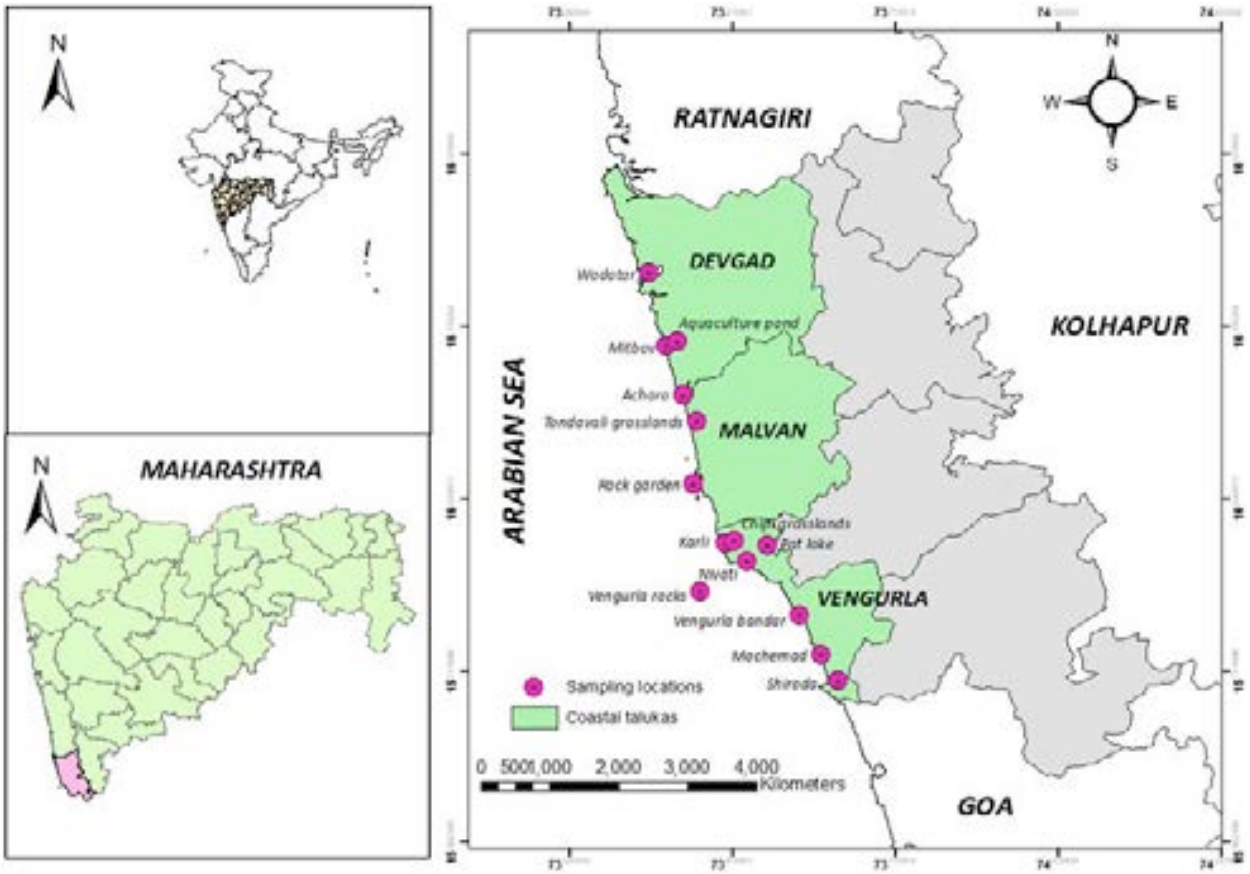

Figure 1. Bird sampling locations in Sindhudurg coast.

village in Vengurla Taluka. In one of the islets, breeding activities of the Greater Crested Tern *Thalasseus bergii*, Bridled Tern *Onychopriyon anaethetus* and Roseate Tern *Sterna dougallii* have been reported (Lainer 2003). This rocky islet is partially covered with combinations of tall grasses and short herb species. The terns exploit the bare rocky portions of the island for nesting.

Man-modified habitats: Modified wetlands such as agriculture fields (largely paddy), saltpans and aquaculture ponds are found in patches throughout the coastal areas. Saltpan is practised in Vengurla Taluka on a minor scale. Aquaculture ponds are common along upstream regions of the district. Common aquaculture taxa are prawns and crabs.

MATERIALS AND METHODS

We chose seven estuaries/creeks: Achara and Karli in Malvan Taluka, Mitbav and Wadatar in Devgad Taluka, and Mochemad, Vengurla Bandar and Nivati in Vengurla Taluka for observing the coastal birds (Fig. 1). These sites were sampled once a month and thus, we visited the whole stretch of Sindhudurg coast either by bike or jeep covering diverse terrestrial habitats (moist deciduous, grasslands, agriculture fields, commercial plantations) and inland wetland habitats (Pat Lake and puddles in grasslands during the monsoon) in the area. All observations on terrestrial birds were opportunistic. Quantitative data was collected only for wetland birds, which were the focus of the project but we recorded other birds as well to make a comprehensive list of birds. Bird surveys were carried out from December 2014 to December 2016. We made observations between 05.30h and 18.00h and conducted occasional night surveys for owls *Strigiformes*. Besides, we also conducted four offshore surveys to Vengurla rocks for pelagic birds using fishing boats. The number of days spent at each field site and taluka is provided in (Table 1). Although we used the Nikon spotting scope 20–60x for bird observation, sufficient photographs were taken to confirm species identities. Nearly 80% of our observations were photo documented. We did not collect abundance data for the terrestrial birds; thus, we categorised all the birds

Image 1 . Natural habitats surveyed in Sindhudurg coast: a—Intertidal sandy mudflat | b—Mangroves | c—Rocky shore | d—Vengurla rocks | e—Pat lake | f—Laterite grasslands | g—Sandy beach.

Image 2. Man-modified habitats in Sindhudurg coast: a—Aquaculture pond | b—Agriculture lands | c—Saltpan.

into three broad categories based on the percentage of sighting such as >3% (Common), 1–3 % (uncommon) and <1% (rare). The percentage of sightings were expressed by dividing frequency of sightings of particular species by total visits. We referred Birdlife International (2019) for threat status of each species.

On the basis of our observation from December 2014 to December 2016 in the district, the distribution status of each bird species was categorized into five groups.

Resident: Occurs in the district throughout the year.

Winter Migrant: Species occur only during winter (September to May).

Passage Migrant: Species occurs in the study area for refueling their energy during onward and return migration.

Vagrant: Species is either not resident/not regular breeding or wintering migrant but has a few stray records.

Monsoon Migrant: Species occurs only during the monsoon.

RESULTS

We collated 307 species belonging to 78 families, and 22 orders for the coastal areas of Sindhudurg District (Table 2) and 283 species recorded during our survey, and 24 more species compiled from the published literature. During this study, species richness was the highest in Vengurla Taluka (256 species) followed by Malvan Taluka (247), and Devgad Taluka (213) (Table 2). Order Passeriformes (111 species) had the highest species representation followed by Charadriiformes (63), Accipitriformes (20) and Pelecaniformes (15) and one species each represented in Procellariiformes and Gaviiformes (Fig. 2). Out of 283 species, 175 (~62%) and 108 (~38%) were resident and migratory birds respectively. Among 108 migrants, 93 winter migrants, 13 passage migrants, one monsoon migrant and one vagrant were recorded.

Sindhudurg coast used to support three Critically Endangered species namely Red-headed Vulture *Sarcogyps calvus*, White-rumped Vulture *Gyps bengalensis*, and Indian Vulture *G. indicus*, one Endangered Great Knot *Calidris tenuirostris*, and Vulnerable Woolly-necked Stork *Ciconia episcopus* but during our study we could not record any vultures (Table 2 & Image 3). The vulture population has crashed all over the country. Besides, 14 more species fall under the Near Threatened category of IUCN. Grey-headed Bulbul *Pycnonotus priocephalus*, Malabar Grey Hornbill *Ocyceros griseus*, Crimson-backed Sunbird *Leptocoma minima*, and Vigor's Sunbird *Aethopyga vigorsii* are the birds recorded from the Sindhudurg coast that are considered to be endemic to the Western Ghats. Based on the sighting percentage, 151, 114 and 18 species were common, uncommon and rare, respectively. Location and date of observation of species sighted less than <1%

Table 1. Site and taluka wise sampling effort in Sindhudurg District.

	Taluka	Site	Number of days visited between December 2014-December 2016					Total effort
			Mar–May	Jun–Aug	Sep–Nov	Dec–Feb	Sub total	
1	Devgad	Vijaydurg	2	2	5	5	14	85
2		Phanse	1	1	1	2	5	
3		Kunkeshwar	1	2	2	1	6	
4		Mithmumbri	2	1	1	2	6	
5		Wadatar	7	5	6	9	27	
6		Mitbav	7	6	5	9	27	
7	Malvan	Achara	7	5	5	10	27	87
8		Tondavali grassland	1	2	6	2	11	
9		Rock Garden	8	4	4	8	24	
10		Tarkarli	7	5	5	8	25	
11	Vengurla	Karli	7	5	5	8	25	157
12		Chipi grassland	2	3	3	3	11	
13		Nivati	8	5	5	8	26	
14		Pat Lake	3	3	2	4	12	
15		Vengurla Bandar	7	5	5	10	27	
16		Mochemad	8	5	5	9	27	
17		Shiroda saltpans	7	5	5	8	25	
18		Vengurla rocks	-	-	4	-	4	
		Total	**85**	**64**	**74**	**106**	**329**	**329**

of total visits are given below (Image 3).

Interesting sight records

Northern Shoveler *Anas clypeata*: It was recorded twice: once in an aquaculture pond of Mitbav on 6 November 2016, and another on 8 November 2016 at Shiroda saltpans of Vengurla. On both occasions, the flock size was >10.

Ruddy Shelduck *Tadorna ferruginea*: One bird was seen in an aquaculture pond at Mitbav on 6 November 2016.

Painted Stork *Mycteria leucocephala*: A sub-adult bird was seen in a saltpan at Shiroda on 22 January 2015 (Image 3).

Amur Falcon *Falco amurensis*: One bird was seen in grassland at Vengurla on 20 November 2015 (Image 3).

Common Buzzard *Buteo buteo*: We recorded it three times: one individual each at Vijayadurg and Kochara beach on 22 October 2015, and three individuals at Kochara beach on 10 October 2016.

Masked Booby *Sula dactylatra*: Three sub-adults were seen resting on rocky islets close to Vengurla rocks on 7 October 2015 (Image 3).

Eurasian Oystercatcher *Haematopus ostralegus*: We saw it twice: two birds on 8 October 2016 at Tambaldeg beach, and a solitary bird was observed on 11 July 2016 at Devbag beach.

Crab-plover *Dromas ardeola*: A bird was observed in mixed flocks of gulls at Mochemad beach on 7 November 2016 (Image 3).

Great Knot *Calidris tenuirostris*: Two birds were seen on mudflats of Mochemad estuary on 6 November 2016.

Ruff *Philomachus pugnax*: A sparse flock of 10 birds were seen at Tondavali laterite grasslands on 18 September 2015 (Image 3).

Black-tailed Godwit *Limosa limosa:* This solitary bird was seen twice at Shiroda saltpans, first on 5 January 2015 and the second on 28 March 2016.

Bar-tailed Godwit *Limosa lapponica*: One individual was sighted on 28 October 2016 at Mitbav aquaculture pond (Image 3).

Great Thick-knee *Esacus recurvirostris*: The solitary bird was observed in the intertidal mudflat of Vengurla Bandar on 26 December 2016 (Image 3).

Oriental Pratincole *Glareola maldivarum*: A pair was sighted in Tondavali grasslands on 20 August 2016. Tentatively identified as Oriental Pratincole after examining the wing pattern visible in the videos we took

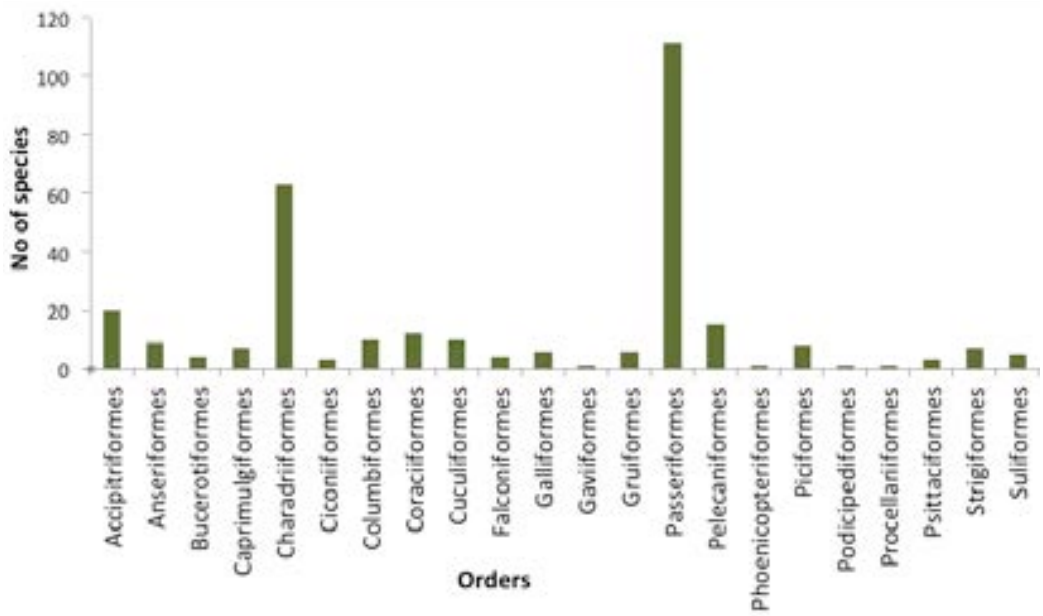

Figure 2. Species richness of birds in different orders.

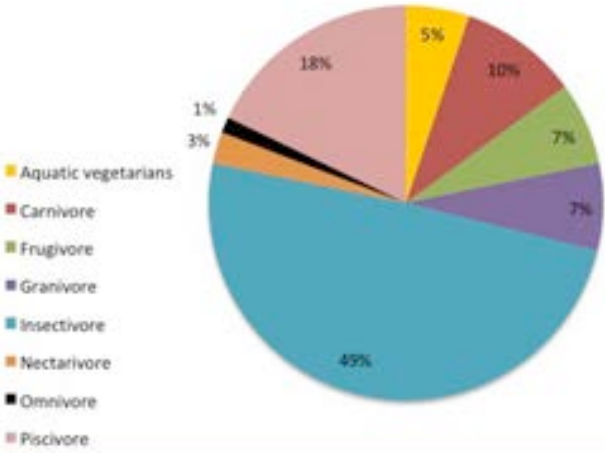

Figure 3. Species composition of birds in different foraging guilds.

(Video 1) (Gerald Driessens in litt. 8 August 2018).

Wilson's Storm-petrel *Oceanites oceanicus*: A single bird was seen foraging actively in the open sea on 23 October 2015 between Nivati beach and Vengurla rocks

Common Tern *Sterna hirundo*: During our offshore surveys between Nivati beach and Vengurla rocks on 23 October 2015 four individuals were observed at Burnt Island.

Little Tern *Sternula albifrons*: The solitary bird was seen in Shiroda saltpans on 12 March 2015.

Brown-breasted Flycatcher *Muscicapa muttui*: Observed one individual in wooded areas of Karli village on 19 October 2016.

Although we observed Steppe Eagle *Aquila nipalensis*, Grey-headed Fish Eagle *Ichthyophaga ichthyaetus*, Indian Spotted Eagle *A. hastata*, Red-necked Falcon *Falco chicquera*, Eurasian Sparrowhawk *Accipiter nisus* and Common Ringed Plover *Charadrius hiaticula* during our study, due to a lack of good quality photographs we excluded them from the list. The foraging guild of birds species in the district was dominated by insectivores (~49%) followed by piscivores (~18%), and omnivores and nectarivores showed least contribution (1% to 3%) (Fig. 3).

DISCUSSION

Altogether, we collated 307 species from Sindhudurg coast, which represents nearly 84% of birds recorded from the Sindhudurg District as a whole (eBird 2019). Out of these 307 species, four are endemic to the Western Ghats. A multi-observer effort of 997 and 838 eBird lists yielded 364 and 340 bird species in Sindhudurg and Ratnagiri districts respectively while the present study recorded 283 bird species from 329 field days in the coastal areas indicating the high diversity of birds in these talukas. Despite inadequate sampling effort in the Western Ghats, year-round monitoring along the Sindhudurg coast raised the total species pool. A few stretches of natural forests (for example moist deciduous forests) in the district were surveyed, but intensive sampling was not conducted. Accordingly, the

Table 2. Birds from three coastal talukas of Sindhudurg District, Maharashtra

						Talukas			
	Common name	Scientific name	Observers	Status	Occurrence	Vengurla	Malvan	Devgad	Habitats used
	Galliformes/ Phasianidae								
1	Indian Peafowl	*Pavo cristatus*	P, K	R	C	+	+	+	GS
2	Grey Junglefowl	*Gallus sonneratii*	P	R	U	+	+	-	WD
3	Red Spurfowl	*Galloperdix spadicea*	P, V	R	U	+	+	-	WD
4	Grey Francolin	*Francolinus pondicerianus*	P	R	C	+	+	+	GS,WD
5	Common Quail	*Coturnix coturnix*	P	W	U	+	-	-	GS,WD
6	Jungle Bush Quail	*Perdicula asiatica*	P, V, K	R	U	+	-	+	GS,WD
	Charadriiformes/ Turnicidae								
7	Barred Buttonquail	*Turnix suscitator*	P, V, K	R	U	-	+	-	GS
	Anseriformes/ Anatidae								
8	Lesser Whistling-duck	*Dendrocygna javanica*	P, K	R/LM	C	+	+	+	FW, AQ, SAL
9	Cotton Pygmy-goose	*Nettapus coromandelianus*	P	R/LM	C	+	-	-	FW
10	Indian Spot-billed Duck	*Anas poecilorhyncha*	P	R/LM	C	+	-	-	FW
11	Northern Pintail	*Anas acuta*	P	W	U	+	-	-	FW
12	Garganey	*Spatula querquedula*	P	W	U	+	-	-	FW, AQ, SAL
13	Common Teal	*Anas crecca*	P	W	U	+	-	+	FW, AQ, SAL, MG
14	Gadwall	*Anas strepera*	P	W	U	+	-	+	FW, AQ, SAL, MG
15	Northern Shoveler	*Anas clypeata*	P	W	R	+	+	+	FW, AQ, SAL
16	Ruddy Shelduck	*Tadorna ferruginea*	P	W	R	-	-	+	FW, AQ
	Podicipediformes/ Podicipedidae								
17	Little Grebe	*Tachybaptus ruficollis*	P, V, K	R/LM	C	+	+	+	FW, SAL
	Phoenicopteriformes/ Phoenicopteridae								
18	Greater Flamingo	*Phoenicopterus roseus***	A	Unknown	Unknown	-	+	-	INMDF
	Ciconiiformes/ Ciconiidae								
19	Painted Stork	*Mycteria leucocephala*	P	W	R	+	-	-	AQ
20	Asian Openbill	*Anastomus oscitans*	P	W	C	+	+	+	FW, MG, AG
21	Woolly-necked Stork	*Ciconia episcopus*	P	R/LM	C	+	-	-	SBH, AQ, SAL
	Pelecaniformes/ Threskiornithidae								
22	Black-headed Ibis	*Threskiornis melanocephalus*	P	R/LM	C	+	+	+	FW, AG, MG, AQ, SAL
23	Glossy Ibis	*Plegadis falcinellus*	P	W	U	+	-	-	FW, AG, AQ
24	Red-naped Ibis	*Pseudibis papillosa*	P	R/LM	U	+	-	-	FW, AG, AQ
	Pelecaniformes/ Ardeidae								
25	Cinnamon Bittern	*Ixobrychus cinnamomeus*	P, V	R/LM	U	-	+	-	GS, MG
26	Yellow Bittern	*Ixobrychus sinensis*	P	R/LM	U	+	-	-	MG, VGR
27	Cattle Egret	*Bubulcus ibis*	P, K	R/LM	C	+	+	+	FW, MG, AQ, SAL, RSH, SBH, GS, AG
28	Little Egret	*Egretta garzetta*	P, K	R/LM	C	+	+	+	FW, MG, AQ, SAL, AG, RSH
29	Intermediate Egret	*Mesophoyx intermedia*	P, K	R/LM	C	+	+	+	FW, MG, AQ, SAL, AG
30	Great Egret	*Casmerodius albus*	P, K	R/LM	C	+	+	+	FW, MG, AQ, SAL, AG, RSH

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
31	Western Reef Egret	*Egretta gularis*	P, A, K, L	W	C	+	+	+	FW, MG, AQ, SAL, RSH, SBH
32	Grey Heron	*Ardea cinerea*	P, A, K	W	C	+	+	+	FW, MG, AQ, SAL, INMDF
33	Purple Heron	*Ardea purpurea*	P, K	R/LM	C	+	+	+	FW, MG, AQ, SAL
34	Indian Pond Heron	*Ardeola grayii*	P, K, L	R/LM	C	+	+	+	FW, MG, AQ, SAL, AG, RSH, INMDF
35	Striated Heron	*Butorides striata*	P, V, K	R	C	+	+	+	FW, MG, RSH, SAL, AQ
36	Black-crowned Night Heron	*Nycticorax nycticorax*	P, V, K	R	U	+	+	-	FW
	Suliformes/ Anhingidae								
37	Darter	*Anhinga melanogaster*	P	W	U	+	+	-	MG, AQ
	Suliformes/ Phalacrocoracidae								
38	Little Cormorant	*Phalacrocorax niger*	P, K	R/LM	C	+	+	+	FW, MG, AQ, SAL
39	Indian Cormorant	*Phalacrocorax fuscicollis*	P	W	U	+	+	+	FW, MG, AQ, SAL
	Suliformes/ Sulidae								
40	Masked Booby	*Sula dactylatra*	P	V	R	+	+	-	VGR
41	Brown Booby	*Sula leucogaster***	J	Unknown	Unknown	+	-	-	OFSH
	Falconiformes/ Falconidae								
42	Common Kestrel	*Falco tinnunculus*	P, H, V, L, PKT, K	W	C	+	+	+	GS, VGR
43	Peregrine Falcon	*Falco peregrinus calidus*	P, V, A, L	W	C	+	+	+	SBH, PL
44	Amur Falcon	*Falco amurensis*	P	PM	R	+	-	-	GS
45	Eurasian Hobby	*Falco subbuteo*	P	W	U	+	-	-	GS
	Accipitriformes/ Pandionidae								
46	Osprey	*Pandion haliaetus*	P, V, A, L	W	C	+	+	+	GS, SBH,MG, INMDF, AQ, SAL, VGR
	Accipitriformes/ Accipitridae								
47	Red-headed Vulture	*Sarcogyps calvus***	V	Unknown	Unknown	-	+	-	WD
48	White-rumped Vulture	*Gyps bengalensis***	V, KM	Unknown	Unknown	+	+	+	WD
49	Indian Vulture	*Gyps indicus***	V	Unknown	Unknown	+	+	+	WD
50	Black Kite	*Milvus migrans*	P, K	R/LM	C	+	+	+	GS, SBH, RSH, MG, INMDF, AQ, SAL, WD
51	Brahminy Kite	*Haliastur Indus*	P, L, K	R	C	+	+	+	GS, SBH, RSH, MG, INMDF, AQ, SAL, WD
52	Black-winged Kite	*Elanus caeruleus*	P	R	C	+	+	+	GS, AQ, WD, AG
53	White-bellied Sea Eagle	*Haliaeetus leucogaster*	P, H, A, PKT, PA, KMP, L, KT	R	C	+	+	+	GS, SBH, RSH, INMDF, AQ, SAL, MG, WD, VGR
54	Crested Serpent Eagle	*Spilornis cheela*	P, V, K	R	C	+	+	+	GS, AQ, MG, WD
55	Eurasian Marsh Harrier	*Circus aeruginosus*	P, V, L	W	C	+	+	+	FW, GS, MG
56	Pallid Harrier	*Circus macrourus*	P	W	U	+	+	+	GS
57	Montagu's Harrier	*Circus pygargus*	P	W	U	+	+	+	GS
58	Shikra	*Accipiter badius*	P, V, K	R	C	+	+	+	GS, PL, AG, WD

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
59	Besra	*Accipiter virgatus*	P	R	U	+	+	-	GS, WD
60	Oriental Honey-buzzard	*Pernis ptilorhynchus*	P	R	C	+	+	+	GS, PL, MG, VGR, WD
61	White-eyed Buzzard	*Butastur teesa*	P, K	R	U	+	+	+	GS, WD
62	Common Buzzard	*Buteo buteo*	P	PM	R	+	-	+	GS, WD
63	Bonelli's Eagle	*Aquila fasciata*	P	R	U	-	+	+	GS, WD
64	Booted Eagle	*Hieraaetus pennatus*	P	W	C	+	+	+	GS, SBH, MG
65	Crested Hawk Eagle	*Nisaetus cirrhatus*	P, K	R	C	+	+	+	GS, SBH, MG ,PL, WD
	Strigiformes/ Tytonidae								
66	Barn Owl	*Tyto alba*	P	R	C	+	+	+	GS, WD
	Strigiformes/ Strigidae								
67	Indian Scops Owl	*Otus bakkamoena*	P, V, K	R	U	+	+	-	GS, WD
68	Brown Hawk Owl	*Ninox scutulata***	V	Unknown	Unknown	-	+	-	GS, WD
69	Brown Wood Owl	*Strix leptogrammica***	V	Unknown	Unknown	-	-	+	WD
70	Jungle Owlet	*Glaucidium radiatum*	P, V, K	R	C	+	+	+	GS, WD
71	Spotted Owlet	*Athene brama*	P, V	R	C	+	+	+	GS, WD
72	Brown Fish Owl	*Ketupa zeylonensis*	P	R	U	-	+	-	FW, GS
	Caprimulgiformes/ Caprimulgidae								
73	Jungle Nightjar	*Caprimulgus indicus*	P, V	R	C	+	+	+	WD, GS
74	Indian Nightjar	*Caprimulgus asiaticus*	P, V	R	U	+	+	+	WD, GS
75	Savanna Nightjar	*Caprimulgus affinis*	P, V	R	U	-	+	-	WD, GS
	Gruiformes/ Rallidae								
76	Slaty-legged Crake	*Rallina eurizonoides*	P	W	U	-	+	-	FW
77	Slaty-breasted Rail	*Gallirallus striatus*	P, V	R	U	+	+	-	MG
78	White-breasted Waterhen	*Amaurornis phoenicurus*	P, K	R	C	+	+	+	FW, MG, AQ, AG
79	Common Moorhen	*Gallinula chloropus*	P	R/LM	U	+	-	-	FW, SAL
80	Eurasian Coot	*Fulica atra*	P	R/LM	U	+	-	-	FW, SAL
81	Purple Swamphen	*Porphyrio porphyrio*	P, V	R/LM	C	+	+	-	FW
	Charadriiformes/ Jacanidae								
82	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	P, K	R/LM	C	+	+	-	FW
83	Bronze-winged Jacana	*Metopidius indicus*	P	R/LM	C	+	-	-	FW
	Charadriiformes/ Haematopodidae								
84	Eurasian Oystercatcher	*Haematopus ostralegus*	P	PM	R	-	+	+	SBH
	Charadriiformes/ Recurvirostridae								
85	Black-Winged Stilt	*Himantopus himantopus*	P, V	R	C	+	+	+	AQ, SAL
	Charadriiformes/ Dromadidae								
86	Crab-plover	*Dromas ardeola*	P	PM	R	+	-	-	SBH
	Charadriiformes/ Charadriidae								
87	Little Ringed Plover	*Charadrius dubius*	P, V, K	W	C	+	+	+	AQ, SAL, SBH, GS
88	Kentish Plover	*Charadrius alexandrinus*	P, V	W	C	+	+	+	SBH,INMDF, MG, AQ

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
89	Lesser Sand Plover	*Charadrius mongolus*	P, V	W	C	+	+	+	SBH, INMDF, MG, AQ, SAL, GS, RSH
90	Greater Sand Plover	*Charadrius leschenaultii*	P	W	C	+	+	+	SBH, INMDF, MG, AQ
91	Pacific Golden Plover	*Pluvialis fulva*	P	W	C	+	+	+	SBH, INMDF, MG, AQ, SAL, GS, AG, RSH
92	Grey Plover	*Pluvialis squatarola*	P, V	W	U	+	+	+	SBH, AQ, SAL, INMDF
93	Yellow-wattled Lapwing	*Vanellus malabaricus*	P, V	R/LM	C	+	+	+	GS, AG
94	Red-wattled Lapwing	*Vanellus indicus*	P, K	R	C	+	+	+	MG, AQ, SAL, GS, AG,FW
	Charadriiformes/ Rostratulidae								
95	Greater Painted-snipe	*Rostratula benghalensis*	P	R	U	+	-	-	GS, AQ
	Charadriiformes/ Scolopacidae								
96	Ruff	*Philomachus pugnax*	P	PM	R	-	+	-	GS
97	Common Snipe	*Gallinago gallinago*	P, K	W	C	+	+	+	GS, AG, AQ
98	Black-tailed Godwit	*Limosa limosa*	P	PM	R	+	-		SAL
99	Bar-tailed Godwit	*Limosa lapponica*	P	PM	R	-	-	+	AQ, INMDF
100	Whimbrel	*Numenius phaeopus*	P, V	W	C	+	+	+	SBH, INMDF, MG, AQ, SAL, GS
101	Eurasian Curlew	*Numenius arquata*	P	W	C	+	+	+	SBH, INMDF, MG, AQ, GS
102	Common Redshank	*Tringa totanus*	P, K	W	C	+	+	+	SBH, INMDF, MG, AQ, SAL
103	Common Greenshank	*Tringa nebularia*	P	W	C	+	+	+	SBH, INMDF, MG, AQ, SAL, AG
104	Marsh Sandpiper	*Tringa stagnatilis*	P	W	U	+	+	+	AQ, SAL
105	Green Sandpiper	*Tringa ochropus*	P	W	U	+	+	+	AQ, SAL, GS, AG
106	Wood Sandpiper	*Tringa glareola*	P, K	W	C	+	+	+	AQ, SAL, GS, FW, AG
107	Terek Sandpiper	*Xenus cinereus*	P	W	C	+	+	+	SAT, SBH, INMDF, MG
108	Common Sandpiper	*Actitis hypoleucos*	P, A, PA, L, K	W	C	+	+	+	AQ, SAL, SBH, INMDF, MG, RSH, FW, GS, AG
109	Ruddy Turnstone	*Arenaria interpres*	P, V, A, G, KMP, PA, L	W	C	+	+	+	SBH, RSH, GS
110	Little Stint	*Calidris minuta*	P	W	C	+	+	+	AQ, SAL, SBH, INMDF, RSH, GS
111	Temminck's Stint	*Calidris temminckii*	P	W	C	+	+	+	AQ, SAL
112	Sanderling	*Calidris alba*	P, V	W	U	+	+	+	SBH, INMDF
113	Curlew Sandpiper	*Calidris ferruginea*	P, V	W	U	+	+	+	SBH, INMDF, AQ, SAL, RSH
114	Great Knot	*Calidris tenuirostris*	P	PM	R	+	-	-	INMDF, SBH
115	Broad-billed Sandpiper	*Limicola falcinellus*	P	W	U	+	+	+	SAT, SBH, INMDF
116	Dunlin	*Calidris alpina*	P	W	U	+	+	+	AQ, SAL, INMDF, SBH
	Charadriiformes/ Glareolidae								
117	Small Pratincole	*Glareola lacteal*	P	R/LM	U	+	-	-	ASL, SBH

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
118	Oriental Pratincole	*Glareola maldivarum*	P	W	R	-	+	-	GS
	Charadriiformes/ Burhinidae								
119	Great Thick-knee	*Esacus recurvirostris*	P	R/LM	R	+	-	-	FW, INMDF
120	Indian Thick-knee	*Burhinus indicus***	V	Unknown	Unknown	-	+	-	FW, GS
	Charadriiformes/ Laridae								
121	Pallas's Gull	*Ichthyaetus ichthyaetus*	P	W	C	+	+	+	SBH, OFSH, INMDF
122	Heuglin's Gull	*Larus heuglini*	P, V, L	W	C	+	+	+	SBH, OFSH, RSH, INMDF
123	Steppe Gull	*Larus barabensis*	P	W	U	+	+	+	SBH, OFSH, INMDF
124	Slender-billed Gull	*Chroicocephalus genei*	P	W	C	+	+	+	SBH, OFSH, INMDF
125	Brown-headed Gull	*Chroicocephalus brunnicephalus*	P, V, A, L	W	C	+	+	+	SBH, OFSH, INMDF, RSH
126	Black-headed Gull	*Chroicocephalus ridibundus*	P, G, L	W	C	+	+	+	SBH, OFSH, INMDF, RSH
127	Gull-billed Tern	*Gelochelidon nilotica*	P	W	C	+	+	+	SBH, INMDF
128	Lesser Crested Tern	*Thalasseus bengalensis*	P, V, A, L,VK, KMP, KD	W	C	+	+	+	SBH, INMDF, VGR
129	Greater Crested Tern	*Thalasseus bergii*	P, V, A, M, VK, PA, KMP, L	R	C	+	+	+	SBH, INMDF, VGR
130	Caspian Tern	*Hydroprogne caspia*	P, A, L	W	U	+	+	+	SBH, INMDF
131	Sandwich Tern	*Thalasseus sandvicensis*	P, G, L	W	U	+	+	+	SBH, INMDF
132	River Tern	*Sterna aurantia*	P, PA	R/LM	U	+	-	-	FW
133	Little Tern	*Sternula albifrons*	P, A, G	R/LM	R	+	+	-	FW, SAL
134	Roseate Tern	*Sterna dougallii*	P, H, A, VK, PA, KMP, L	R/LM	U	+	-	-	VGR
135	Common Tern	*Sterna hirundo*	P, PA, L	W	R	-	+	-	OFSH
136	Whiskered Tern	*Chlidonias hybrida*	P	W	U	+	+	+	AQ, SAL, INMDF, SBH
137	White-cheeked Tern	*Sterna repressa***	V, M, PA, L	Unknown	Unknown	+	+	-	OFSH
138	Sooty Tern	*Onychoprion fuscatus*	P, A, M, PA, L	PM	U	+	-	+	OFSH
139	Bridled Tern	*Onychoprion anaethetus***	V, A, M, VK, PA, KMP, L	Unknown	Unknown	+	-	-	VGR, OFSH
140	Brown Noddy	*Anous stolidus***	L	Unknown	Unknown	+	-	-	OFSH
	Charadriiformes/ Stercorariidae								
141	Brown Skua	*Stercorarius antarcticus***	ED	Unknown	Unknown	-	+	-	OFSH
142	Arctic Skua	*Stercorarius parasiticus***	L	Unknown	Unknown	+	-	-	OFSH
143	Pomarine Skua	*Stercorarius pomarinus***	PA	Unknown	Unknown	+	-	-	OFSH
	Procellariiformes/ Oceanitidae								
144	Wilson's Storm-petrel	*Oceanites oceanicus*	P	PM	R	+	-	-	OFSH
	Gaviiformes/ Gaviidae								
145	Red-throated Diver	*Gavia stellata***	AV	Unknown	Unknown	-	-	+	OFSH
	Columbiformes/ Columbidae								
146	Common Pigeon	*Columba livia*	P, H, V, A, PKT, PA, KMP, L MP, K	R	C	+	+	+	WD, GS, VGR
147	Laughing Dove	*Stigmatopelia senegalensis*	P	R	C	+	+	+	WD, GS
148	Spotted Dove	*Stigmatopelia chinensis*	P, K	R	C	+	+	+	WD, GS

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
149	Red Collared Dove	*Streptopelia tranquebarica*	P, K	R/LM	U	+	+	+	WD, GS
150	Emerald Dove	*Chalcophaps indica*	P	R	C	+	+	+	WD
151	Oriental Turtle Dove	*Streptopelia orientalis*	P, L	R	U	+	+	+	WD, GS
152	Eurasian Collared Dove	*Streptopelia decaocto*	P	R	C	+	+	+	WD, GS
153	Grey-fronted Green Pigeon	*Treron affinis*	P	R/LM	U	+	+	-	WD
154	Yellow-footed Green Pigeon	*Treron phoenicopterus*	P, K	R/LM	C	+	+	+	WD
155	Orange-breasted Green Pigeon	*Treron bicinctus*	P	PM	U	+	+	-	WD
	Psittaciformes/ Psittaculidae								
156	Vernal Hanging Parrot	*Loriculus vernalis*	P, K	R	C	+	+	+	WD
157	Rose-ringed Parakeet	*Psittacula krameri*	P, K	R	C	+	+	+	WD, PL
158	Plum-headed Parakeet	*Psittacula cyanocephala*	P, K	R/LM	C	+	+	+	WD, PL
	Cuculiformes/ Cuculidae								
159	Grey-bellied Cuckoo	*Cacomantis passerinus***	V	Unknown	Unknown	+	+	-	WD, GS
160	Jacobin Cuckoo	*Clamator jacobinus*	P	W	U	+	+	+	WD
161	Common Hawk Cuckoo	*Hierococcyx varius*	P, K	R/LM	C	+	+	+	WD
162	Banded Bay Cuckoo	*Cacomantis sonneratii*	P, V	R/LM	C	+	+	-	WD
163	Eurasian Cuckoo	*Cuculus canorus*	P	PM	U	-	+	+	WD
164	Lesser Cuckoo	*Cuculus poliocephalus*	P	PM	U	-	+	-	WD, GS
165	Asian Koel	*Eudynamys scolopaceus*	P, V, K	R	C	+	+	+	WD, MG, GS
166	Southern Coucal	*Centropus sinensis parroti*	P, K	R	C	+	+	+	WD, MG, GS
167	Blue-faced Malkoha	*Rhopodytes viridirostris*	P, V	R	U	+	+	+	WD, MG
168	Sirkeer Malkoha	*Taccocua leschenaultii***	V	Unknown	Unknown	-	+	-	WD
	Caprimulgiformes/ Hemiprocnidae								
169	Crested Treeswift	*Hemiprocne coronate*	P, V	R	C	-	-	+	GS
	Caprimulgiformes/ Apodidae								
170	Asian Palm Swift	*Cypsiurus balasiensis*	P, V, A	R	C	+	+	+	WD, FW
171	Indian Swiftlet	*Collocalia unicolor*	P, V, A, L, MB, PKT	R	U	+	-	-	VGR
172	Little Swift	*Apus affinis*	P, L	R	C	+	+	+	WD, FW, VGR
	Coraciiformes/ Coraciidae								
173	Indian Roller	*Coracias benghalensis*	P, V, K	R/LM	C	+	+	+	GS, WD, AG, FW
174	Eurasian Roller	*Coracias garrulus*	P	W	U	+	+	+	GS, WD
	Coraciiformes/ Alcedinidae								
175	Common Kingfisher	*Alcedo atthis*	P	R	C	+	+	+	FW, INMDF, MG, AQ, SAL
176	Stork-billed Kingfisher	*Pelargopsis capensis*	P, V, K	R/LM	U	+	+	+	FW, MG
177	White-throated Kingfisher	*Halcyon smyrnensis*	P, V, K	R	C	+	+	+	MG, FW, INMDF, SBH, AQ, SAL, GS
178	Black-capped Kingfisher	*Halcyon pileata*	P, V	W	U	+	+	+	MG, INMDF
179	Oriental Dwarf Kingfisher	*Ceyx erithaca*	P	MM	U	-	+	-	MG
180	Pied Kingfisher	*Ceryle rudis*	P, K	R/LM	U	+	+	+	FW, MG, AQ, SAL

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
	Coraciiformes/ Meropidae								
181	Green Bee-eater	*Merops orientalis*	P, K	R	C	+	+	+	FW, WD, GS, AQ, SAL
182	Chestnut-headed Bee-eater	*Merops leschenaultia*	P	W	C	+	+	+	FW, WD, GS
183	Blue-tailed Bee-eater	*Merops philippinus*	P, V	W	U	-	+	-	GS, WD
184	Blue-bearded Bee-eater	*Nyctyornis athertoni***	K	Unknown	Unknown	-	+	-	WD
	Bucerotiformes/ Upupidae								
185	Common Hoopoe	*Upupa epops*	P, V, L, K	R	C	+	+	+	WD, GS
	Bucerotiformes/ Bucerotidae								
186	Malabar Grey Hornbill	*Ocyceros griseus*	P	R	U	-	+	-	WD
187	Malabar Pied Hornbill	*Anthracoceros coronatus*	P, V, K	R	C	+	+	+	WD, PL, GS, MG
188	Indian Grey Hornbill	*Ocyceros birostris*	P, K	R/LM	U	+	+	+	WD
	Piciformes/ Megalaimidae								
189	Brown-headed Barbet	*Megalaima zeylanica*	P, K	R	C	+	+	+	WD
190	Coppersmith Barbet	*Megalaima haemacephala*	P, K	R	C	+	+	+	WD
191	White-cheeked Barbet	*Megalaima viridis*	P	R	U	+	+	-	WD
	Piciformes/ Picidae								
192	Rufous Woodpecker	*Micropternus brachyurus*	P	R	U	-	-	+	WD, PL
193	Lesser Goldenback	*Dinopium benghalense*	P, V, K	R	C	+	+	+	WD, PL
194	Greater Goldenback	*Chrysocolaptes lucidus*	P	R	U	+	-	-	WD, PL
195	Yellow-crowned Woodpecker	*Dendrocopos mahrattensis*	P, V, K	R	U	-	+	-	WD
196	White-naped Woodpecker	*Chrysocolaptes festivus***	V	Unknown	Unknown	-	-	+	WD
	Passeriformes/ Pittidae								
197	Indian Pitta	*Pitta brachyura*	P, V	W	U	-	+	+	WD
	Passeriformes/ Artamidae								
198	Ashy Woodswallow	*Artamus fuscus*	P	R	C	+	+	+	WD
	Passeriformes/ Vangidae								
199	Common Woodshrike	*Tephrodornis pondicerianus*	P, V	R	C	+	+	+	PL, WD
200	Bar-winged Flycatcher-shrike	*Hemipus picatus*	P	R	U	+	-	-	WD
	Passeriformes/ Aegithinidae								
201	Common Iora	*Aegithina tiphia*	P, K	R	C	+	+	+	PL, WD
	Passeriformes/ Campephagidae								
202	Black-headed Cuckooshrike	*Coracina melanoptera*	P, V, L	R/LM	C	+	+	+	WD
203	Small Minivet	*Pericrocotus cinnamomeus*	P, V, K	R	C	+	+	+	PL, WD
204	Orange Minivet	*Pericrocotus flammeus*	P, K	R	U	-	+	-	WD
205	Large Cuckooshrike	*Coracina macei*	P	R	U	-	+	-	WD
	Passeriformes/ Laniidae								
206	Brown Shrike	*Lanius cristatus*	P	W	U	+	-	-	WD, GS
207	Long-tailed Shrike	*Lanius schach*	P, K	R	C	+	+	+	WD, GS
208	Bay-backed Shrike	*Lanius vittatus*	P, K	R	U	+	+	+	WD, GS

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
	Passeriformes/ Dicruridae								
209	Black Drongo	*Dicrurus macrocercus*	P, L, K	R	C	+	+	+	FW, WD, GS, MG
210	Ashy Drongo	*Dicrurus leucophaeus*	P	W	C	+	+	+	WD
211	White-bellied Drongo	*Dicrurus caerulescens*	P	R/LM	U	+	+	+	WD
212	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	P, V, K	R	C	+	+	+	WD
213	Bronzed Drongo	*Dicrurus aeneus*	P	R	U	+	-	-	WD
	Passeriformes/ Oriolidae								
214	Indian Golden Oriole	*Oriolus kundoo*	P, K	W	C	+	+	+	WD, GS
215	Black-hooded Oriole	*Oriolus xanthornus*	P, V, K	R	C	+	+	+	WD, GS
	Passeriformes/ Rhipiduridae								
216	White-browed Fantail	*Rhipidura aureola*	P	R	C	+	+	+	WD, PL, MG
217	White-spotted Fantail	*Rhipidura albicollis albogularis*	P, V, K	R	U	-	+	+	WD, PL, MG
	Passeriformes/ Monarchidae								
218	Black-naped Monarch	*Hypothymis azurea*	P	R	U	+	+	-	WD
219	Asian Paradise-flycatcher	*Terpsiphone paradisi*	P, V, K	R/LM	U	+	+	+	WD
	Passeriformes/ Corvidae								
220	Rufous Treepie	*Dendrocitta vagabunda*	P, K	R	C	+	+	+	WD, GS
221	House Crow	*Corvus splendens*	P, L, K	R	C	+	+	+	WD, SBH, RSH, MG
222	Indian Jungle Crow	*Corvus culminatus*	P, PKT, K	R	C	+	+	+	WD, SBH, RSH, MG
	Passeriformes/ Paridae								
223	Great Tit	*Parus major*	P	R	U	+	+	+	WD
224	Indian Yellow Tit	*Parus aplonotus*	P	R	C	+	+	-	WD
	Passeriformes/ Hirundinidae								
225	Dusky Crag Martin	*Ptyonoprogne concolor*	P	R	C	-	+	+	WD
226	Eurasian Crag Martin	*Ptyonoprogne rupestris*	P	W	U	+	+	+	WD
227	Wire-tailed Swallow	*Hirundo smithii*	P, V, K	R	C	+	+	+	WD, GS, AQ, SAL, FW
228	Red-rumped Swallow	*Cecropis daurica*	P, K	R	C	+	+	+	WD, GS, AQ, SAL, FW
229	Barn Swallow	*Hirundo rustica*	P	W	U	+	-	-	FW
230	Streak-throated Swallow	*Petrochelidon fluvicola*	P, V	R/LM	U	+	-	-	FW
	Passeriformes/ Alaudidae								
231	Rufous-tailed Lark	*Ammomanes phoenicura*	P	R	U	+	+	+	GS
232	Oriental Skylark	*Alauda gulgula*	P	R	C	+	+	+	GS
233	Greater Short-toed Lark	*Calandrella brachydactyla*	P, L	W	U	+	+	-	GS
234	Malabar Lark	*Galerida malabarica*	P, K	R	C	+	+	+	GS
	Passeriformes/ Pycnonotidae								
235	Red-vented Bulbul	*Pycnonotus cafer*	P, K	R	C	+	+	+	WD, GS, MG, PL
236	White-browed Bulbul	*Pycnonotus luteolus*	P, V	R	U	+	+	+	WD, GS, MG
237	Red-whiskered Bulbul	*Pycnonotus jocosus*	P, K	R	C	+	+	+	WD, GS, MG, PL
238	Grey-headed Bulbul	*Pycnonotus priocephalus*	P	R	U	+	+	-	WD

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						Vengurla	Malvan	Devgad	
	Passeriformes/ Cisticolidae								
239	Grey-breasted Prinia	*Prinia hodgsonii*	P, K	R	C	+	+	+	WD, GS
240	Ashy Prinia	*Prinia socialis*	P, K	R	C	+	+	+	WD, GS
241	Plain Prinia	*Prinia inornata*	P, K	R	C	+	+	+	WD, GS
242	Jungle Prinia	*Prinia sylvatica*	P	R	C	+	+	+	WD, GS
243	Zitting Cisticola	*Cisticola juncidis*	P, K	R	U	+	+	-	GS, AG
244	Common Tailorbird	*Orthotomus sutorius*	P, K	R	C	+	+	+	WD, GS, FW, MG
	Passeriformes/ Acrocephalidae								
245	Blyth's Reed Warbler	*Acrocephalus dumetorum*	P	W	U	+	+	+	FW
246	Booted Warbler	*Iduna caligata*	P	W	U	-	+	-	WD
247	Clamorous Reed Warbler	*Acrocephalus stentoreus*	P, V	W	U	+	+	+	WD
	Passeriformes/ Phylloscopidae								
248	Greenish Warbler	*Phylloscopus trochiloides*	P, V	W	U	+	+	+	MG, WD
	Passeriformes/ Timaliidae								
249	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	P, V	R	U	+	+	-	WD
250	Tawny-bellied Babbler	*Dumetia hyperythra*	P	R	U	-	+	-	WD
	Passeriformes/ Leiothrichidae								
251	Jungle Babbler	*Turdoides striata*	P, V, K	R	C	+	+	+	WD, GS, PL
252	Large Grey Babbler	*Turdoides malcolmi*	P	R	U	+	+	+	WD
253	Brown-cheeked Fulvetta	*Alcippe poioicephala*	P, V	R	U	-	+	-	WD
	Passeriformes/ Pellorneidae								
254	Puff-throated Babbler	*Pellorneum ruficeps*	P	R	U	+	+	+	WD
	Passeriformes/ Sylviidae								
255	Yellow-eyed Babbler	*Chrysomma sinense*	P, V	R	U	-	+	+	WD
	Passeriformes/ Zosteropidae								
256	Oriental White-eye	*Zosterops palpebrosus*	P	R	U	-	-	+	WD
	Passeriformes/ Sturnidae								
257	Brahminy Starling	*Sturnia pagodarum*	P, V	R/LM	C	+	+	+	WD, GS
258	Chestnut-tailed Starling	*Sturnia malabarica*	P	W	C	+	+	+	WD, MG, GS, PL
259	Rosy Starling	*Pastor roseus*	P	W	C	+	+	+	GS
260	Common Myna	*Acridotheres tristis*	P, K	R	C	+	+	+	WD,GS, MG
261	Jungle Myna	*Acridotheres fuscus*	P, K	R	C	+	+	+	WD,GS, MG
	Passeriformes/ Turdidae								
262	Orange-headed Thrush	*Zoothera citrina*	P, V, K	R	C	+	+	+	WD
263	Indian Blackbird	*Turdus merula simillimus***	V	Unknown	Unknown	-	+	+	WD
	Passeriformes/ Muscicapidae								
264	Oriental Magpie Robin	*Copsychus saularis*	P, K	R	C	+	+	+	WD, GS, FW, MG
265	Indian Robin	*Saxicoloides fulicatus*	P, PKT, K	R	C	+	+	+	WD, GS, FW, MG
266	Blue Throat	*Luscinia svecica*	P	W	U	-	-	+	WD
267	White-rumped Shama	*Copsychus malabarica*	P	R	U	+	-	-	WD

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
268	Black Redstart	*Phoenicurus ochruros*	P	W	U	-	-	+	WD
269	Common Stonechat	*Saxicola torquatus*	P	W	C	+	+	+	GS
270	Pied Bushchat	*Saxicola caprata*	P, V, K	R	C	+	+	+	AG, GS, SAL
271	Blue Rock Thrush	*Monticola solitarius*	P, H, A, L	W	C	+	+	+	RSH
272	Blue-capped Rock Thrush	*Monticola cinclorhynchus***	V	Unknown	Unknown	+	-	-	WD
273	Malabar Whistling Thrush	*Myophonus horsfieldii*	P, V	R	U	-	-	+	WD
274	Asian Brown Flycatcher	*Muscicapa dauurica*	P, V, L	W	U	+	-	+	WD
275	Brown-breasted Flycatcher	*Muscicapa muttui*	P	W	R	+	-	-	WD
276	Tickell's Blue Flycatcher	*Cyornis tickelliae*	P, K	R	C	+	+	+	WD, MG
277	Verditer Flycatcher	*Eumyias thalassinus***	V	Unknown	Unknown	-	-	+	WD
	Passeriformes/ Stenostiridae								
278	Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*	P	W	U	+	-	-	WD
	Passeriformes/ Chloropseidae								
279	Golden-fronted Leafbird	*Chloropsis aurifrons*	P	R	C	+	+	+	WD
280	Jerdon's Leafbird	*Chloropsis jerdoni*	P, V, K	R	C	+	+	+	WD
	Passeriformes/ Dicaeidae								
281	Pale-billed Flowerpeckar	*Dicaeum erythrorhynchos*	P, K	R	C	+	+	+	WD
282	Thick-billed Flowerpecker	*Dicaeum agile*	P, V, K	R	C	+	+	+	WD
283	Nilgiri Flowerpecker	*Dicaeum concolor*	P, K	R	U	-	+	-	WD
	Passeriformes/ Nectariniidae								
284	Purple-rumped Sunbird	*Leptocoma zeylonica*	P, V, K	R	C	+	+	+	WD, PL, MG
285	Purple Sunbird	*Cinnyris asiaticus*	P	R	C	+	+	+	WD, PL, MG
286	Loten's Sunbird	*Cinnyris lotenia*	P	R	U	+	+	+	WD, PL
287	Vigor's Sunbird	*Aethopyga vigorsii*	P, K	R	U	-	+	-	WD
288	Crimson-backed Sunbird	*Leptocoma minima***	MU	Unknown	Unknown	-	+	-	WD
	Passeriformes/ Passeridae								
289	House Sparrow	*Passer domesticus*	P, K	R	C	+	+	+	WD
290	Chestnut-shouldered Petronia	*Gymnoris xanthocollis*	P, K	R	C	+	+	+	WD, GS
	Passeriformes/ Ploceidae								
291	Baya Weaver	*Ploceus philippinus*	P, K	R	C	+	+	+	FW, AG, GS
	Passeriformes/ Estrildidae								
292	Indian Silverbill	*Euodice malabarica*	P	R	C	+	+	+	AG, GS
293	Scaly-breasted Munia	*Lonchura punctulata*	P	R	C	+	+	+	AG, MG, GS
294	Black-headed Munia	*Lonchura malacca*	P	R	C	+	+	+	AG, MG, GS
295	White-rumped Munia	*Lonchura striata*	P, V, K	R	C	+	+	+	AG, MG, GS
	Passeriformes/ Motacillidae								
296	Forest Wagtail	*Dendronanthus indicus***	V	Unknown	Unknown	-	+	-	WD, GS
297	White Wagtail	*Motacilla alba*	P, V	W	C	+	+	+	FW, AQ, SAL
298	White-browed Wagtail	*Motacilla maderaspatensis*	P, K	R	C	+	+	+	AG, FW, AQ, SAL
299	Citrine Wagtail	*Motacilla citreola*	P	W	U	-	+	-	AG
300	Yellow Wagtail	*Motacilla flava*	P, K	W	U	+	+	+	AG

	Common name	Scientific name	Observers	Status	Occurrence	Talukas			Habitats used
						Vengurla	Malvan	Devgad	
301	Grey Wagtail	*Motacilla cinerea*	P, L	W	C	+	+	+	AG, FW, AQ, SAL
302	Paddyfield Pipit	*Anthus rufulus*	P, K	R	C	+	+	+	AG, GS, AQ, SAL
303	Tawny Pipit	*Anthus campestris*	P	W	U	+	-	-	AG, GS, AQ, SAL
304	Blyth's Pipit	*Anthus godlewskii*	P	W	U	+	-	+	AQ, SAL
305	Tree Pipit	*Anthus trivialis*	P, V	W	U	+	+	+	GS
306	Richard's Pipit	*Anthus richardi*	P	W	U	+	+	+	GS
	Passeriformes/ Emberizidae								
307	Black-headed Bunting	*Emberiza melanocephala*	P	W	U	-	+	+	GS

Observers: ** Species compiled from published literature, P—Present study, H—Hume 1876, V—Vidal 1880, 1883, A—Adbulali 1940, 1942, 1983, ED—Editors 1958, M—Madsen 1988, G—Gole 1994, VK—Katdare 2001, PKT—Pande et al. 2001, PA—Pande 2002a,b, L—Lainer 2003, KMP—Katdare et al. 2004a, MP—Mahabal & Pande 2006, KD—Kasambe & Deshmukh 2011, KM—Kamble et al. 2011, J—Jamalabad 2013, K—Khot 2016, AV—Avalaskar 2016, MU—Shrikrishna Ramachandra Magdum pers. obs. 2017.
Status: R—Resident, W—Winter migrant, PM—Passage migrant, MM—Monsoon migrant, V—Vagrant.
Occurrence: Common—percentage of sighting >3%, uncommon—percentage of sighting 1–3 %, rare—percentage of sighting <1%, Unknown—species compiled from literature.
Habitats: GS—Grasslands, WD—Woodlands, FW—Fresh water habitat, AQ—Aquaculture Pond, SAL—Saltpan, INMDF—Intertidal sandy mudflats, MG—Mangroves, SBH—Sandy beach, RSH—Rocky shore, VGR—Vengurla Rocks, OFSH—Offshore waters, AG—Agriculture lands.

total species pool compiled here is only for the coastal regions of the district and more species might be added if one samples the forest areas of the district. Among the talukas surveyed, from Vengurla Taluka, a maximum richness of birds was recorded, and availability of mosaic of habitats within the coastal areas might be attributed for this pattern. The lower diversity of birds in Devgad Taluka can be associated with the presence of laterite grasslands along the coasts and an absence of a large extent of woody vegetation in the coastal areas.

We also observed a few rare and under-recorded species of western Maharashtra, as mentioned in Prasad (2006), such as Amur Falcon, Common Buzzard, Montagu's Harrier *Circus pygargus*, Wilson's Storm-petrel, Masked Booby, Eurasian Oystercatcher, Great Knot, Crab-plover, Orange-breasted Green Pigeon, and Brown-breasted Flycatcher during the study along the Sindhudurg coast.

In comparison with Vidal's (1880) observation, we did not record a few species such as the Red-headed Vulture, the Indian Vulture, the White-rumped Vulture, Sirkeer Malkoha *Taccocua leschenaultii*, Indian Blackbird *Turdus merula simillimus*, Brown Hawk Owl *Ninox scutulata*, Brown Wood Owl *Strix leptogrammica*, Verditer Flycatcher *Eumyias thalassinus*, Forest Wagtail *Dendronanthus indicus*, Blue-capped Rock Thrush *Monticola cinclorhynchus*, Indian Thick-knee *Burhinus indicus*, Grey-bellied Cuckoo *Cacomantis passerinus*, White-naped Woodpecker *Chrysocolaptes festivus*, Bridled Tern *Onychoprion anaethetus*, and the White-cheeked Tern *Sterna repressa*, during our sampling. In addition, Greater Flamingo *Phoenicopterus roseus* (Abdulali 1942), Brown Skua *Stercorarius antarcticus* (Editors 1958), Pomarine Skua *Stercorarius pomarinus* (Pande 2002a), Arctic Skua *Stercorarius parasiticus* and Brown Noody *Anous stolidus* (Lainer 2003), Brown Booby *Sula leucogaster* (Jamalabad 2013), Blue-bearded Bee-eater *Nyctyornis athertoni* (Khot 2016), Red-throated Diver *Gavia stellata* (Avalaskar 2016), and Crimson-backed Sunbird *Leptocoma minima* (Shrikrishna Ramachandra Magdum pers. obs. 7.xii.2017) were reported from the Sindhudurg coast but not observed by us during the study. The vulture species had been distributed all over India but due to a recent population decline, their distribution range has shrunk to a few pockets, and this might be the reason for not encountering these species in all historical occurrence localities. Furthermore, as discussed earlier, less sampling in the northern Western Ghats might be the reason for missing a few forest dwelling species. Although we conducted coastal and offshore surveys, we did not carry out any surveys during the monsoon months because Bridled Tern is anticipated to occur in Vengurla rocks during the monsoon (Lainer 2003). In brief, less sampling in the Western Ghats and offshore, and rare nature of some species (e.g., Red-throated Diver) might be the reason for missing these birds.

Grey-headed Bulbul has been stated to occur in the Western Ghats, i.e., from Kanyakumari to Goa (Grimmett et al. 2011), but we observed this bird

Image 3. Rare and threatened birds observed along the Sindhudurg coast: a—Bar-tailed Godwit | b—Crab-plover | c—Painted Stork | d—Ruff | e—Masked Booby | f—Great Knot | g—Amur Falcon | h—Great Thick-knee | i—Woolly-necked Stork | j—Eurasian Oystercatcher.

along the Sindhudurg coast. Prasad (2006) listed the Grey-headed Bulbul in Maharashtra's bird list, but comprehensive information about their distribution and occurrences within Maharashtra is not available. We saw it repeatedly (5 times in two locations: Hadi and Karli villages) in the forested areas along the Malvan and Vengurla coasts, and hence we speculate that the distribution range of this species in Maharashtra might be much more widespread than predicted. A survey of the Grey-headed Bulbul's population in abutting districts may be attempted to define the distribution range of this Near-threatened and endemic species of the Western Ghats. Vidal (1880) also had observed a few forest dwelling species, viz., Indian Scimitar Babbler, Blue-capped Rock Thrush, and Malabar Whistling Thrush in wooded habitats close to the coast.

Out of 283 species, 38% of them were migratory. Sindhudurg coast attracts migratory species especially transcontinental migratory birds like waders. Almost 68% of resident birds occur throughout the year in the district. The high richness of resident birds in Sindhudurg is attributed to the availability of the mosaic of habitats. It has also been observed in other studies that variation in bird populations among sites in different seasons and the same has been attributed to environmentally dependent factors such as the change in local and regional habitat conditions (Ericia et al. 2005).

Unregulated tourism and associated developments, sand mining, stray dogs and conversion of laterite grasslands are the major threats to the coastal avifauna in the district. Mochemad (95 species; 10,000 gulls of six species), Karli (117 species; 5,000 gulls of six species), Mitbav (103 species; 2,000 gulls of six species) estuaries, and grasslands such as Tondavali and Chipi (a breeding ground for lapwings, larks; alternative foraging ground for wintering shorebirds; foraging ground for wintering raptors) in Sindhudurg coast support a greater richness of terrestrial and wetland birds. Considering the high species richness of birds and livelihood dependency of humans on the coastal zones, a few estuaries namely Mochemad, Karli and Mitbav estuaries may be recognized as community reserve or conservation reserve to manage the ecosystem sustainably for long-term conservation of these estuaries and sub-habitats therein. Also, these three sites can be perceived as Important Bird and Biodiversity Areas of BirdLife International as they fulfill the IBA criteria.

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COMMUNICATION

Greater One-horned Rhinoceros *Rhinoceros unicornis* (Mammalia: Perissodactyla: Rhinocerotidae) population census in the Rajiv Gandhi Orang National Park, Assam, India

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Deba Kumar Dutta [1] & **Parikshit Kakati** [2]

[1,2] WWF-India, Block-A-16, Flat No-103 Basistha, Guwahati, Assam 781029, India.
[1] debakumerdutta@gmail.com (corresponding author), [2] parik67@gmail.com

Abstract: The complete-count of rhino or rhino census is an integral part of conservation and management of wild rhino-bearing areas of Assam. The direct count of rhinos in their wild habitat continues as the accepted method of determining rhino population. As a part of the periodic process, the Rajiv Gandhi Orang National Park (RGONP) organized a one-day direct rhino count on 2 April 2018. The results showed 1% increment of the population after a gap of six years. Such slow increment is considered to be a matter of concern. More research is necessary for better understanding of the population dynamics and identification of factors for better management of rhino population at RGONP.

Keywords: Complete-count, direct count, habitat management, Indian Rhino, trend.

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Author details: Dr Deba Kumar Dutta has been providing technical support on rhino monitoring and research activities to translocated rhinos at Assam since the year 2008. He is an IUCN/SSC AsRSG member and also an IUCN/SSC AsRSG (Asian Rhino Specialist Group) accredited instructor in monitoring the Greater One-Horned Rhino. Dr Parikshit Kakati has been providing veterinary support and other research activities in Assam since the year 2017.

Author contribution: DKD has contributed to the field studies, scientific analysis, and the write-up. PK has critically analysed all findings.

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INTRODUCTION

The complete count of animals or animal census is arranged over a specified interval of time, at a specified point in an area (Overton 1971). This process is possible only if the area is relatively small and the animals are more or less conspicuous and easy to locate (Gopal 2012). The complete count of the Greater One-horned Rhino (GOR) *Rhinoceros unicornis* usually termed 'rhino census' is an integral part of conservation and management of wild rhino-bearing areas of Assam. The direct count of rhinos in their wild habitat continues to be an acceptable method of rhino census due to the following reasons (Lahan & Sonowal 1973):

(i) It is difficult to use the prescribed known method like 'sample count' because of the nature of the terrain, the tall, thick cover of the grassland habitat of the rhino.

(ii) The preferred habitat of rhinos is not evenly distributed; thus the distribution of rhino population is not even, as expected in a wild habitat.

(iii) Traversing in tall and thick grassland is difficult except with elephants.

The wildlife authority of India normally conducts a complete count or rhino census for each population in an interval of 3–5 years (Mukherjee & Sengupta 1999). Distribution and abundance of rhino population in Nepal is also being assessed by direct count methods every three years (Subedi et al. 2011). The complete count method is also conducted to count large mammals like Indian Elephants (Singh 1978; Nair & Gadgil 1980); Nilgiri Tahr (Davidar 1978); Barasingha (Schaller 1967); Blackbuck (Daniel 1967; Nair 1976) at intervals of 3–4 years.

On 2 April 2018, the Rajiv Gandhi Orang National Park (RGONP) conducted a total count of wild rhinos after a gap of six years. There were 100 wild rhinos counted in the year 2012 (Assam Forest Department 2014).

Study Area

The RGONP is situated on the southern bank of river Brahmaputra encompassing 79.27km^2 of riverine landscapes (Fig. 1). The word 'Orang' has its origin from the Assamese word 'Oor' which means 'the end'. Historically, it was the eastern boundary of the king Arimatta or Vaidyadeva's kingdom (bounded by the river Panchnoi).

The conservation history of Orang started as game reserve in 1915; later, it was proposed as a wildlife sanctuary encompassing 79.27km^2 in 1985. The proposed sanctuary was upgraded to a national park in the year 1999. It was declared the fifth tiger reserve of Assam in the year 2016. The Orang Tiger Reserve extends over a total area of 492.46km^2 in which 79.28km^2 is the core area and 413.18km^2 is the buffer area including a part of the Brahmaputra River.

This protected area is a part of the Brahmaputra riverine landscape and famous for its floral and faunal diversity like Indian Elephants *Elephus maximus*, Pygmy Hogs *Porcula salvania*, and Bengal Florican *Houbaropsis bengalensis* besides Greater One-horned Rhinos and Bengal Tigers. Because of its rich biodiversity and habitat similarity, Orang is also called Mini Kaziranga.

METHODS

The rhino census requires a properly skilled and motivated staff, a coordinated well designed planning, a system of control for data quality and logistical support (DNPWC 2009). RGONP authority had arranged sufficient logistics, and 32 enumerators were invited from different parts of Assam to volunteer for the smooth accomplishment of the process (Image 1). To carry out the rhino census, the entire RGONP area was divided into 16 counting sectors, each with an average size of 3–4 km^2. These sectors were serially numbered and indicated on a map and were commonly called blocks or compartments and delineated on the basis of habitat, accessibility and general distribution of rhinos (Fig. 2). Each enumerator was assigned one compartment for counting rhinos. The enumerators were provided a kit containing a GPS, a pair of binoculars, one data sheet, compartment map and necessary field guidance. A staff of the forest department was assigned with each enumerator and acted as a helping guide. Six senior forest officials were assigned to coordinate the rhino counting process by radio (wireless) and mobile phones with the enumerators.

Depending on the terrain, an elephant with a mahout or a vehicle was provided for counting the rhinos. Counting was done simultaneously from 05.30h to 09.30h, from a specified starting point for each enumerator and ended at another definite location, usually a specific anti-poaching camp. Rhinos normally graze actively in the morning hours (Laurie 1978; Hazarika et al. 2013; Dutta et al. 2017). Counting was arranged in the morning hours because it helps the rhino count during day time and also helps in the safe return of the enumerators from difficult areas of the park before dark. During the count, details regarding approximate age, sex, spatial information (like terrain, type of vegetations, water sources) and other related

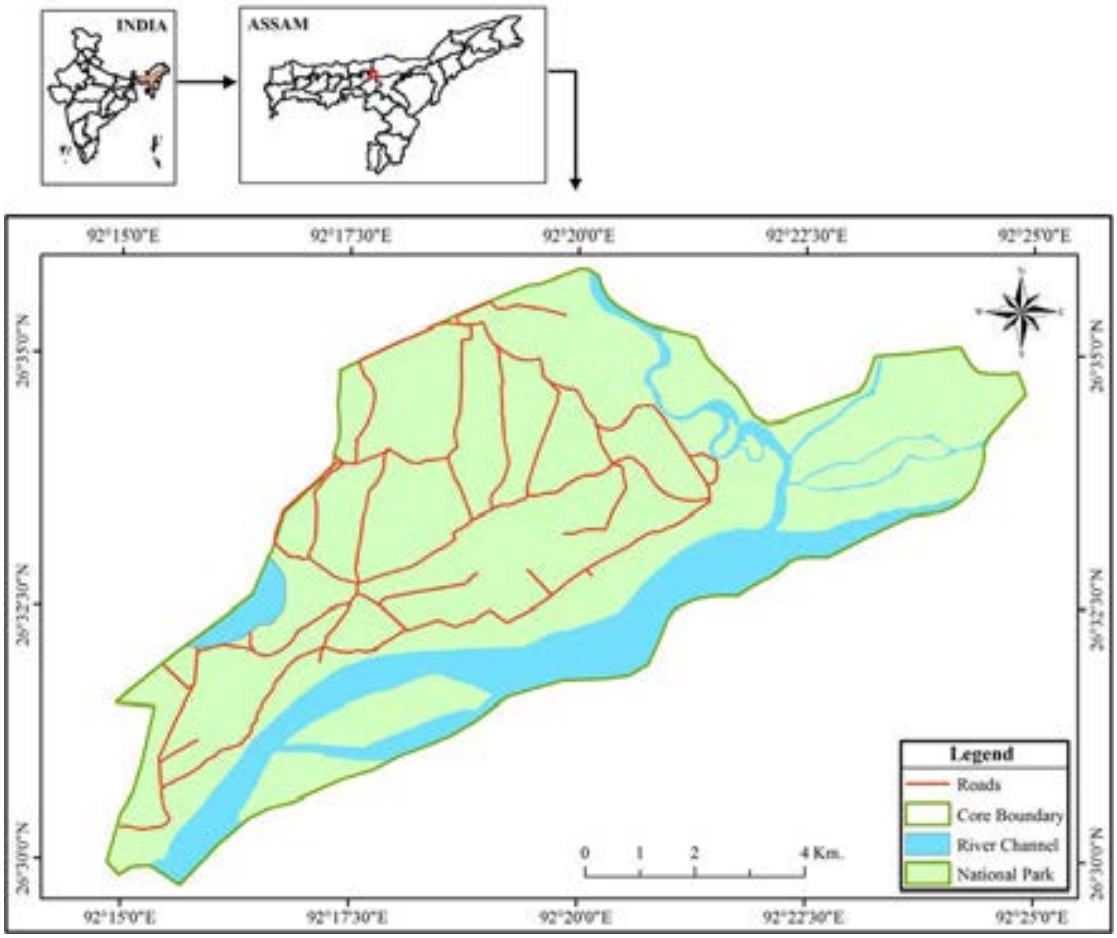

Figure 1. Rajiv Gandhi Orang National Park, Assam, India.

Figure 2. Rhino estimation blocks 2018 in Rajiv Gandhi Orang National Park in Assam, India.

Image 1. The mahout, enumerator, and guide on elephant back.

evidence like time of locations were recorded in the rhino enumerator sheet. The enumerators were advised to notice different features of the rhinos which made it possible to identify individual rhinos on the basis of sex, size, age, horn, ear shapes, skin folds, epidermal knobs, damaged tail, scars and other phenotypic deformities. The rhinos were categorised in the following three age classes, as accepted and adopted by the Asian Rhino Specialist Group (AsRSG) (IUCN/SSC AsRSG 2009).

1. Calves are new-born maximum up to about four years (dependant rhino with mother). A calf is associated with the mother, often moving ahead of the mother. The horn is protruding and the entire body is under developing conditions (Laurie 1978). In RGONP the calves were again segregated into two sub groups (a) below one year and (b) above one year, based on their body growth.

2. The 'sub-adults' are independent rhinos up to the age of six years. They have a small and clean body with undergrowth neck folds. The third neck fold near the shoulder is not distinct. Horns are not grown or protruding. Rump and shoulder folds are not well developed; ribs are buried and are not distinct. The sub-adults usually stay in small groups of 2–3 individuals (Laurie 1978).

3. The 'adults' are more than six years old. Their body is massive and well built. The neck folds are thick and well developed; the upper rump folds are thick and clearly visible; and the shoulder and lower rump folds reach down to the elbow and knees. Both sides of the rumps and shoulders contain distinct knobs. The ribs are distinct and the back is slightly lowered. The horn is fully grown and often eroded because of rubbing on tree trunks and searching for food. The cut marks are common on the ears. The adult female is generally aggressive while protecting the calf (Laurie 1978).

It is difficult to ascertain the sex of the rhinos, so the enumerators were advised to check properly on the basis of the size of the animal, horn shapes, ears, tail, skin folds, group composition and finally looking into external genitalia (IUCN/SSC AsRSG 2009). If an observer was unable to identify the sex, they were advised to put it into the category of 'unsexed' or 'uncertain sex' in each age group.

During the sessions of orientation given, all enumerators were requested to traverse dense grassland as much as possible in search of rhinos and also ensure necessary care and precautions to prevent an accident due to attack by rhinos or other wild animals.

The observer team in charge of the rhino enumeration finally collected all the data sheets immediately from each enumerator of the respective blocks. The final result of the status of rhino population in RGONP was declared after just two hours of enumeration.

RESULTS

For the four hours (05.30–09.30 h) of enumeration efforts, a total of 101 rhinos was recorded from the 13 rhino enumeration blocks of RGONP (Table 1). Three blocks, namely, Belsiri, Bogbeel, and Gaimari, did not record rhinos. In the Magurmari, Pabamari, and Satsimalu blocks more than 10 rhinos were counted. In Satsimalu, 25 rhinos were counted, which was the maximum number during this rhino census.

During enumeration, 66 adult rhinos (22 adult male, 37 adult female and 7 unidentified adults), 13 sub-adults (4 sub-adult males, 5 sub-adult females, and 4 unidentified sub-adults), 22 calves (4 calves below one year old and 18 calves above one year) were identified (Fig. 3). During the enumeration process 6.9% adults (n = 7) and 3.9% sub-adults (n=4) rhinos gender could not be ascertained due to dense vegetation, time lapse of observation and also due to uncomfortable distance

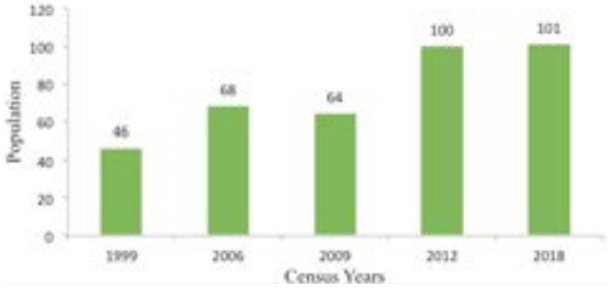

Figure 3. Census figures of Rhinos at Rajiv Gandhi Orang National Park, Assam, India.

Table 1. Rhino enumeration result of different compartments at Rajiv Gandhi Orang National Park, 2018.

	Block	Adult			Sub-adult			Calf		Total
		Male	Female	Unknown sex	Male	Female	Unknown sex	Below 1 year	Above 1 year	
1	Belsiri	0	0	0	0	0	0	0	0	**0**
2	Bogbeel	0	0	0	0	0	0	0	0	**0**
3	Chaila	2	1	2	0	0	1	0	0	**6**
4	Gaimari	0	0	0	0	0	0	0	0	**0**
5	Jhaoni	1	3	0	0	0	0	0	1	**5**
6	Magurmari	4	3	0	2	1	2	0	2	**14**
7	Mulamari	1	1	0	0	0	0	0	0	**2**
8	Oogil	1	2	0	0	0	0	0	1	**4**
9	Pabamari	3	5	0	0	1	0	0	2	**11**
10	Rahmanpur A	2	1	0	0	0	0	0	1	**4**
11	Rahmanpur B	0	3	0	0	1	1	0	2	**7**
12	Ramdas	2	1	0	0	0	0	0	0	**3**
13	Ramkong	0	1	4	1	0	0	0	0	**6**
14	Satsimalu	4	10	0	1	1	0	3	6	**25**
15	Solmari	1	4	0	0	0	0	1	3	**9**
16	Tinkona	1	2	1	0	1	0	0	0	**5**
	Total	**22**	**37**	**7**	**4**	**5**	**4**	**4**	**18**	**101**

between the animal and the enumerator.

DISCUSSION

The maximum numbers reported from three blocks of Magurmari, Satsimalu, and Pabamari could be due to the availability of fodder and wallowing sites for rhinos. Sarma et al. (2012) and Hazarika (2007) observed that rhinos preferred wet alluvial grassland all-round the year in RGONP. According to Sarma et al. (2012), wet alluvial grassland covers 56.69% in Satsimalu area, 37.33% in Magurmari, and 51.09% in Pabamari. Satsimalu & Magurmari are situated in mid-region of the park, and do not have external disturbance factors like domestic cattle grazing, illegal entry of villagers (for fishing, firewood collection and other non-wood forest products).

The visibility of Pabamari block was good as grasslands were burnt recently (Images 2,3). The Gaimari block adjacent to Pabamari also has a better habitat but the enumerator was unable to locate rhinos as the habitat was dense and visibility was very poor. It was very difficult to traverse the areas with an elephant. Both Belsiri and Bogbeel blocks are situated adjacent to village boundaries and rhino movement was minimum. As such, no rhino was counted there.

The process of enumeration is dependent on favourable habitat conditions. The invasion of alien species has degraded the lush green habitat of RGONP. According to Lahkar et al. (2011), *Mimosa* spp., *Mikania micrantha* and *Chromolaena odorata* have rapidly degraded the habitat condition in RGONP. *Mimosa* sp. has affected 11.56km^2 of the park. Thus, these invasive species may harmfully impact habitat utilization patterns as well as the health of rhinos and other wild herbivores. This may be another reason of uneven distribution of rhino numbers in all the blocks. Thus more scientific studies on the impacts of invasive species on the rhinos and the habitat are urgently required.

It was observed that the rhino enumeration process depends on factors like visibility of area and grassland burning (Lahan & Sonowal 1973; Debroy 1986; Hazarika 2007), level of experience of the guide, mahout and trained patrolling elephants, weather conditions and time of enumeration (Lahan & Sonowal 1973). The presence of other wild animals like tigers, wild elephants, buffaloes and enumerator experiences of rhino behaviour and habitat preferences are also factors to be considered. Besides, a sufficient budget is necessary to arrange all logistics without hampering the entire process (Bhatt 2011).

Compared to rhino census figures of 2012, there

Image 2. Habitat in Pabamari block of Rajiv Gandhi Orang National Park, Assam.

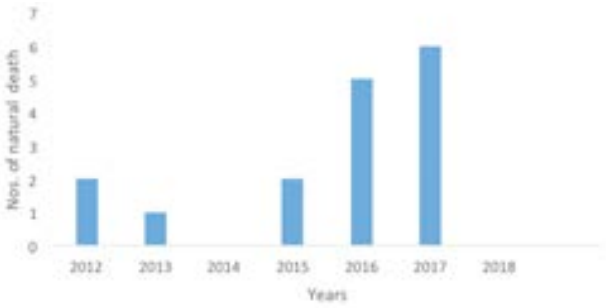

Figure 4. Natural deaths of rhinos in Rajiv Gandhi Orang National Park (2012–2018).

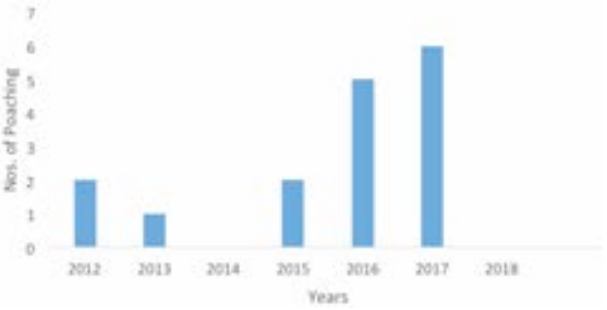

Figure 5. Rhino poaching in Rajiv Gandhi Orang National Park (2012–2018).

was only one additional individual (1%) during the 2018 census (Fig. 3); however, according to government records there were a total of 26 rhino deaths in RGONP in the years 2012–2018 (Figs. 4 & 5). There were 16 natural deaths and 10 deaths due to poaching. As there was no uniform and consistent record showing rhino births in the park itself, it would be difficult to elucidate the fluctuation pattern of rhino population that in turn

Image 3. An adult male Greater One-horned Rhinoceros in Pabamari Compartment of Rajiv Gandhi Orang National Park.

would directly influence the preparation of a population management strategy.

To assess the distribution and abundance of rhino population, uniform and consistent information of birth, death, aging and sex-wise composition is necessary (Laurie 1978). Periodic reports, half yearly or quarterly, may be useful to get the fluctuation patterns in the growth of the rhino population (Bhatt 2011). For a better understanding of population dynamics, more research is necessary to identify the factors for better monitoring of rhino population in the wild.

CONCLUSION

The rhino census or total counting involves every individual rhino in a particular habitat. Care has to be taken to eliminate possibilities of double counting or missing animals during the counting process. It is said that a combination of total count with some suitable sampling procedure is necessary to diminish such error (Gopal 2012). This exercise also supports strengthening of security conditions of the respective rhino-bearing areas due to uniform scans of the entire park areas and identification of probable threats (Barua 1998).

To enumerate and identify rhinos in the wild, a special rhino enumerator training for one week may be necessary for better understanding of rhino behaviour, age structure, sex composition and habitat preferences. The government of Assam or Government of India may develop special rhino enumeration protocol to enhance understanding of the process and to avoid errors.

In Gorumara National Park, West Bengal 43 rhinos were counted through sampling and genetic analysis of dung in the year 2011 (Borthakur et al. 2016). For small rhino populations unique identity based (ID) regular rhino monitoring, or 'sighting based monitoring' may be helpful (Laurie 1978; Patton 2007; Bhatt 2011; Subedi et al. 2011). The ID based rhino monitoring may be used to estimate population in a sighting-mark-resighting framework (Subedi et al. 2011). Regular monitoring of rhinos is essential to determine the progress towards achieving various managerial objectives.

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COMMUNICATION

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Crowding, group size and population structure of the Blackbuck *Antilope cervicapra* (Linnaeus, 1758) (Mammalia: Cetartiodactyla: Bovidae) in the semi-arid habitat of Haryana, India

Deepak Rai [1] & **Jyoti** [2]

[1,2] Department of Zoology, Kurukshetra University, Thanesar, Kurukshetra, Haryana 136119, India.
[1] drbkuk@gmail.com (corresponding author), [2] jyoti.aggroia02@gmail.com

Abstract: To understand the population growth dynamics and life history parameters of the Blackbuck, 24 fortnightly visits were made in and around Lalpur Jheel, Dobhi Village of district Hisar (Haryana) from March 2017 to February 2018. Scan sampling method was used to record the Blackbuck population. In the present study, a total of 68 sightings of Blackbuck were made including a minimum of one sighting per visit to a maximum of seven sightings per visit with group size varying from one individual to a maximum of 58 individuals per sighting. The overall mean group size and crowding of the Blackbuck population were 13.84 ± 1.89 S.E. and 31.31 (N=941 individuals), respectively. The population structure of Blackbuck revealed six different age and sex classes, namely, adult male, adult female, sub-adult male, sub-adult female, yearling male, and fawn. As far as the social organization of the Blackbuck is concerned, six different types of social grouping were recorded, namely lone territorial male (adult male), unimale-unifemale (adult male and adult female), bachelor herd (adult male(s)/ sub-adult male(s)/ yearling male(s)), mixed herd (adult male(s)/ sub-adult male(s)/ yearling male(s)/ adult female(s)/ sub-adult female(s)/ fawn(s)), harem herd (1 adult male/ adult female(s)/ sub-adult female(s)/ fawn(s)), and female herd (adult female(s)/ sub-adult female(s)/ fawn(s)). It was concluded that Blackbuck shows partial social organization as both the solitary and herd were observed during the present study.

Keywords: Antelope, growth dynamics, Hisar District, Lalpur Jheel, life history parameters, social organization, ungulates.

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Author details: Dr Deepak Rai is an Assistant Professor in Department of Zoology, Kurukshetra University, Kurukshetra. His field of research includes ornithology, animal ecology and wildlife conservation. Ms Jyoti is a research scholar and pursuing her PhD from Department of Zoology, Kurukshetra University, Kurukshetra.

Author contribution: Deepak Rai and Jyoti conceived and designed the study. Jyoti collected the field data and prepare rough draft of the manuscript. Deepak Rai guided the research, analyzed the data and wrote the final draft of the manuscript.

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INTRODUCTION

Grouping behaviour in antelopes is largely accompanied by predation pressure, but the maximum group size is limited through dispersion and availability of food resources in a particular area (Jarman 1974). Group size in ungulates also depends on habitat structure as it increases with habitat openness such as on grasslands and decreases with dense vegetation as in scrubby forest area (Lagory 1986). In this context a group can be defined as the numbers of individuals usually present less than 10m apart and behaving in a coordinated fashion when first observed (Mungall 1978). As we consider the group size, it refers to the sum of number of individuals belonging to different age classes and having an integer value n=1 (Ramesh et al. 2012a).

Considering normal distribution of a species, researchers mostly deal with calculating mean group size of a population in most of the ecological studies. Due to changing climatic conditions, however, nowadays normal distribution is converted into clumped distribution especially in birds and mammals (Reiczigel et al. 2008). To overcome these problems, initially Jarman (1974) described a new phenomenon termed as 'typical group size' that reflects the group size as experienced by an average individual, which was later named as 'crowding' by Recizigel et al. (2008). Crowding can be defined as the group size as experienced by an individual in a particular group because average individuals come from a group larger than the mean group size of a population (Recizigel et al. 2008; Ramesh et al. 2012b).

Under demographic changes over time, age structure is an important parameter to understand the population dynamics and various life history parameters (Caughly 1977; Stearns 1992). Along with this, data regarding the sex ratio of a population reflects the reproductive potential of a species (Ramesh et al. 2012b). In ecosystems, antelopes share an important role in maintaining the biodiversity that ensures sustainability of organisms across various trophic levels in the food chain including predators that feed on antelopes and the plant population on which antelopes feed. But it is presumed that due to environmental changes arising through fragmentation, degradation or destruction of natural habitats, deforestation, agricultural expansion, increased urbanization, grazing pressure due to enhanced livestock population and more commonly through illegal hunting and poaching, the population of antelopes is continually declining. Blackbuck being endemic to the Indian subcontinent needs more attention to be explored.

The Blackbuck *Antilope cervicapra* (Linnaeus, 1758) is a medium-sized antelope, the only representative of the sub-family Antilopinae and the genus *Antilope* (Prater 1971). The word antelope is used to describe a number of species of the family Bovidae, but the scientific name *Antilope* is restricted only to the Blackbuck (Ranjitsinh 1989). It is known as 'Kala Hiran' or 'Krishna Mriga' in Hindi due to its distinctive dark brown or black coloration in sharp contrast to white for which the species is named (Mungall 1978; Ranjitsinh 1989; Jhala 1992). Currently, Blackbuck is categorized as Least Concern (IUCN SSC Antelope Specialist Group 2017), which was previously categorized as Near Threatened (Mallon 2008). Despite the overall habitat loss, the conservation status of Blackbuck has improved probably due to unintentional creation of more suitable habitat, i.e., open habitat by converting dense scrub land and woodland to agricultural area (IUCN SSC Antelope Specialist Group 2017). On the other hand, farmers are regularly complaining about their crop damage due to crop raiding by Blackbuck and for this, they are using various protective measures to prevent their crops which may ultimately lead to changes in the normal ecology of Blackbuck. So, the study of ecology and behaviour of Blackbuck is becoming important in such areas where a significant number of Blackbucks are commonly seen by inhabitants and farmers of the villages (Rai & Jyoti 2018).

A number of studies have been conducted on different ecological and behavioural aspects of Blackbuck in India (Gupta & Bhardwaj 1990; Gehlot & Jakher 2007, 2011; Kumar & Rahamani 2008; Vats & Bhardwaj 2009a, b; Mahato et al. 2010; Dookia et al. 2011; Sharma & Sharma 2013; Gangotri & Gangotri 2014; Baskaran et al. 2016; Prashanth et al. 2016; Debata 2017; Sagar & Antony 2017; Meena & Chourasia 2018) and also in Khairapur, Bardia District, Nepal (Bhatta 2008; Khanal & Chalise 2010). Among these, most of the studies were conducted in protected areas of India and fewer studies were conducted outside the protected areas. It is observed that very few studies regarding the ecological aspects of Blackbuck have been conducted in Haryana, especially in district Hisar after Ranjitsinh (1989) who had reported that out of total 4,852 Blackbuck populations in the state of Haryana, 2,410 individuals of blackbuck were recorded from district Hisar alone.

The present study was conducted to record the group size, crowding pattern, herd composition, social behaviour and seasonal variation in sightings of Blackbuck in Lalpur Jheel, Dobhi Village, Hisar (Haryana) which would be helpful in understanding the life history parameters of this species and current status in the study area.

MATERIALS AND METHODS

Study Area

Lalpur Jheel is situated in village Dobhi (29.130^{0}N & 75.505^{0}E) of district Hisar, Haryana (India) at an altitude of 218m and covering an area of about 340 acres (Fig. 1). This area exhibits tropical monsoon climate with hot summers and cool winters. The extreme temperatures and scanty rainfall are unique features of the weather of this area. Based on the climatic conditions of the area, the year is divided into four distinct seasons: summer (March to May), monsoon (June to August), autumn (September to November), and winter (December to February).

In addition to Blackbuck, other ungulate species found in the area include Nilgai *Boselaphus tragocamelus* and Sambar *Rusa unicolor*. As far as the diversity of flora is concerned, the area includes Kikar *Acacia nilotica*, Neem *Azadirachta indica*, Oak *Calotropis procera*, Dub *Cyaodon dactylon*, Shisham *Dalbergia sissoo*, Dhatura *Datura stramonium*, Dhab *Desmostachya bipinnatta*, Safeda *Eucalyptus* sp., Peepal *Ficus riligiosa*, Jand *Prosopis cineraria*, and different types of herbs and shrubs. The study area can be divided into three major habitats such as agricultural land, fallow land and scrubby forest. Major proportion of the study area is covered with scrubby forest having small patches of fallow land and surrounded by agricultural land.

Data Collection and Analysis

To record the group size and herd composition of Blackbuck, visits every fortnight were conducted in Lalpur Jheel, Dobhi Village from March 2017 to February 2018. Following Chopra & Rai (2010), scan sampling

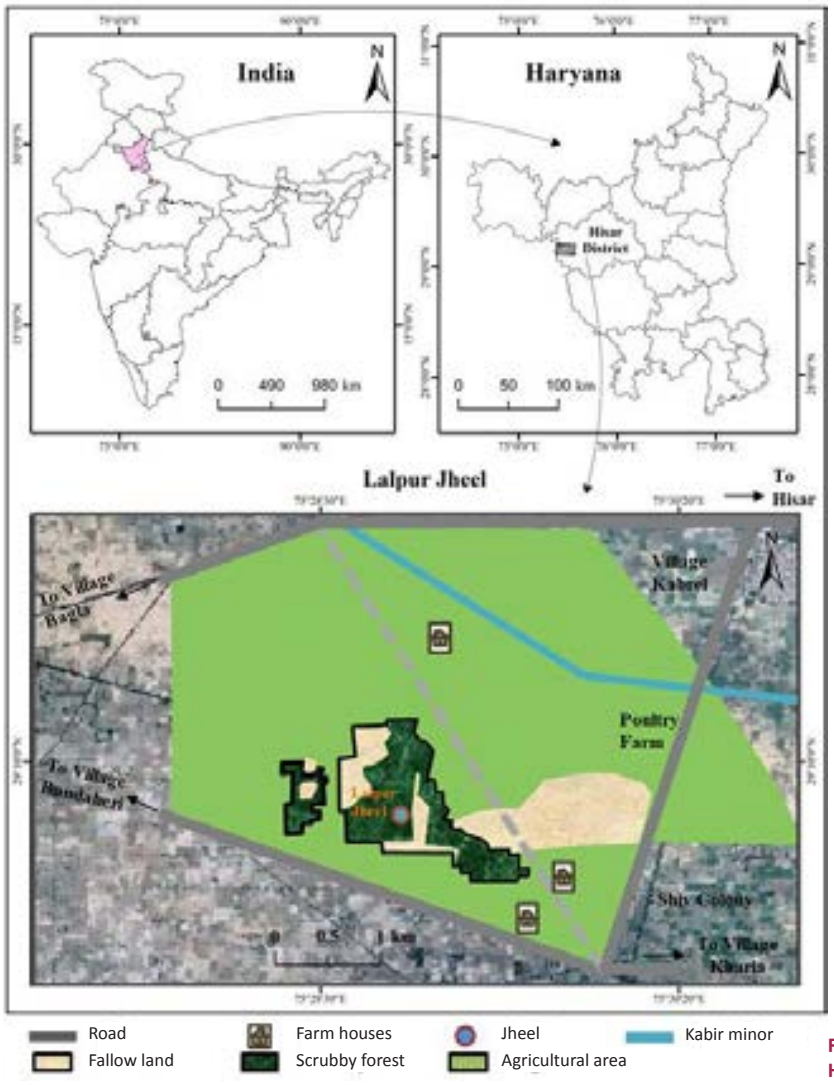

Figure 1. Lalpur Jheel, Dobhi Village in district Hisar, Haryana (India).

method (Altmann 1974) was used to observe Blackbucks using binoculars. The method of instantaneous or scan sampling is in use in various forms of behavior studies, as stated in Altmann (1974), and the method refers to records on current activity of a group or individual at pre-selected time intervals. Photographs in the present study were taken with Canon PowerShot SX50HS digital camera. The time of observation was divided into three diurnal phases, i.e., morning phase (06.30h to 11.00h), noon phase (11.00h to 15.00h), and evening phase (15.00h to 18.30h).

On each sighting of Blackbuck, the number of individuals per group as well as numbers of such groups were recorded (Arcese et al. 1995), followed by recording of data on their age and sex classes. Following Mungall (1978) and Mahato et al. (2010), Blackbucks were categorized into six different age classes namely, adult males (having long horns with 3–4 spiral turns with black and white pelage on dorsal and ventral sides, respectively), sub-adult males (having comparatively short horns with 1–2 spiral horns and dark brown pelage dorsally), yearling males (approximately one year of age with only short spikes like horns having no spiral turn and yellowish pelage dorsally) adult females (more than two years of age having yellowish to tan color dorsally but no spiraling horns), sub-adult females (approximately 1–2 years of age having similar pelage as of adult females but comparatively smaller in size than adult females) and fawn (less than six months of age with light brown pelage but not in contrast to white) including both male and female due to absence of morphological demarcation.

As far as the type of herd is concerned, Blackbuck herds were classified into six different types: lone territorial male (single adult male), unimale-unifemale (one adult male and one adult female), bachelor herd (adult male(s), sub-adult male(s) and yearling male(s)), harem herd (single adult male, adult female(s), sub-adult female(s) and fawn(s)), female herd (adult female(s), sub-adult female(s) and fawn(s)), and mixed herd (adult male(s), sub-adult male(s), yearling male(s), adult female(s), sub-adult female(s) and fawn(s)). Along with mean group size of Blackbuck, mean crowding was also calculated which represents the intensity or infrapopulation size of group from individual's point of view (Reiczigel et al. 2005). Both mean group size and mean crowding were calculated by using program Flocker 1.0 (Reiczigel & Rozsa 2006; Reiczigel et al. 2008) and obtained data was also cross checked by using the following formulae as per Jarman (1982) who used typical group size instead of mean crowding.

$$\text{Mean group size of Blackbuck} = \frac{\text{Number of Blackbucks seen}}{\text{Number of sightings}}$$

$$\text{Mean crowding} = \frac{\sum_{i=0}^{i=n}(x_i)2}{N}$$

where,

x_i = number of individuals in the i^{th} group/sighting

n = number of groups

N = total number of individuals

RESULTS

During the study, a total of 68 sightings of Blackbuck were recorded with a minimum of one sighting (in 5th and 17th periodic visit) per visit to a maximum of seven sightings (4th periodic visit) per visit (Fig. 2). During the eighteenth periodic visit, no sighting of Blackbuck was recorded in the field survey because of the disturbances caused by plying of vehicles for construction of concrete road in the study area. As far as the group size of Blackbuck is concerned, it ranged from 1 to 58 individuals with a mean group size of 13.84 ± 1.89 S.E. and the mean crowding value was 31.31 (N=941 individuals) (Table 1). The lowest mean group size and mean crowding was observed during autumn 2017. In contrast to this, the highest mean group size was observed during winter 2017–18 and the highest mean crowding was recorded during summer 2017, which indicates clumped distribution of Blackbuck. Data also revealed that more than 70% of Blackbuck groups were recorded between group sizes ranging from 1 to 30 individuals in all the seasons.

Fawns were sighted throughout the year but two peaks were observed, i.e., during summer and autumn seasons, reflecting that the peak fawning period in Blackbuck are March to May and September to October. The average adult male: adult female: fawn ratio of Blackbuck was 25.18: 100: 14.91 (N=573 individuals) (Table 2). It was also observed that adult male: sub-adult male: adult female: sub-adult female ratio was 35: 100 which was comparatively higher than the adult male: adult female ratio indicating that the population of Blackbuck is increasing. Data regarding the population structure of Blackbuck revealed that of the 941 individuals of Blackbuck recorded during the one year field survey, 31.15% were males, 62.38% were females, and 6.48% were fawn. Out of 293 male individuals, 35.15% were adult males, 35.15% were sub-adult males, and 29.70% were yearling males. Similarly, out of 587 female individuals, 69.68% were adult females, and

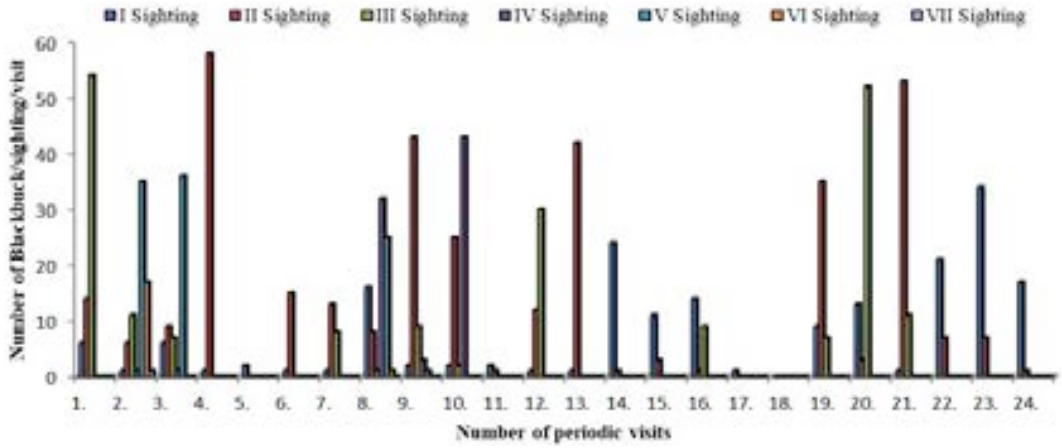

Figure 2. Number of Blackbuck sightings/visit and number of individuals/sighting in and around Lalpur Jheel, Dobhi Village during March 2017 to February 2018.

Table 1. Seasonal grouping patterns of Blackbuck in Lalpur Jheel, Dobhi Village of district Hisar, Haryana (India) from March 2017 to February 2018.

Season(s)	NG	NA	LGO	MC	MeC	MGS	MeGC	SE	Group Size (% of groups)					
									1–10	11–20	21–30	31–40	41–50	>50
Summer (March–May)	20	282	58	35.04	36.00	14.10	6.50	3.84	60.00	20.00	0.00	10.00	0.00	10.00
Monsoon (June–August)	23	281	43	27.33	30.00	12.22	8.00	2.83	60.87	13.04	13.04	4.35	8.70	0.00
Autumn (September–November)	10	107	42	25.71	24.00	10.70	6.00	4.01	60.00	20.00	10.00	0.00	10.00	0.00
Winter (December–February)	15	271	53	33.77	35.00	18.07	11.00	4.35	46.67	20.00	6.67	13.33	0.00	13.33
Annual data	68	941	58	31.31	34.00	13.84	8.00	1.89	57.35	17.65	7.35	7.35	4.41	5.88

NG—number of groups | NA—number of animals | LGO—largest group observed | MC—mean crowding | MeC—median crowding | MGS—mean group size | MeGS—median group size | SE—standard error.

Table 2. Sex ratio of Blackbuck in Lalpur Jheel, Dobhi Village of district Hisar, Haryana (India) from March 2017 to February 2018.

Season(s)	Adult male	Adult female	Fawn	Number of individuals classified
Summer 2017 (March–May)	26.12	100	24.32	167
Monsoon 2017 (June– August)	29.75	100	9.92	169
Autumn 2017 (September–November)	23.53	100	15.69	71
Winter 2017–18 (December–February)	20.63	100	11.11	166
Overall Data	25.18	100	14.91	573

30.32% were sub-adult females (Table 3).

The Blackbucks were sighted more in groups than as solitary animals which reflect their partial social organization. Along with 18 lone territorial male sightings, 13 mixed herds, 18 bachelor herds, 12 harem herds, five female herds, and two unimale-unifemale herds were recorded (Fig. 3; Image 1). Detailed information on seasonal variation in the type of herds observed, group size range and mean group size is given in Table 4.

Table 3. Age structure of Blackbuck in Lalpur Jheel, Dobhi Village of district Hisar, Haryana (India) from March 2017 to February 2018.

Season(s)	AM		SAM		YM		AF		SAF		FW		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Summer 2017 (March–May)	29	10.28	31	10.99	28	9.93	111	39.36	56	19.86	27	9.57	282
Monsoon 2017 (June–August)	36	12.81	40	14.23	32	11.39	121	43.06	40	14.23	12	4.27	281
Autumn 2017 (September–November)	12	11.21	7	6.54	9	8.41	51	47.66	20	18.69	8	7.48	107
Winter 2017–18 (December–February)	26	9.59	25	9.23	18	6.64	126	46.49	62	22.88	14	5.17	271
Overall Data	103	10.95	103	10.95	87	9.25	409	43.46	178	18.92	61	6.48	941

AM—adult male | SAM—sub-adult male | YM—yearling male | AF—adult female | SAF—sub-adult female | FW—fawn.

Table 4. Seasonal variations in the total sightings of Blackbuck, group size range and mean group size ± S.E. in Lalpur Jheel, Dobhi Village from March 2017 to February 2018.

Seasons	Type of herds seen	Total sightings (N)	Group size range	Mean group size ±S.E.
Summer 2017 (March–May)				
	LTM	6	1	1 ± 0
	MxH	7	6–58	27 ± 8.38
	BH	4	2–17	7.75 ± 3.22
	HH	2	14–35	24.5 ± 10.53
	FH	1	7	7 ± 0
Monsoon 2017 (June–August)				
	LTM	6	1	1 ± 0
	UM-UF	2	2	2 ± 0
	MxH	2	25–32	28.5 ± 3.51
	BH	8	2–25	9.63 ± 2.82
	HH	4	13–43	32.25 ± 7.11
	FH	1	8	8 ± 0
Autumn 2017 (September–November)				
	LTM	4	1	1 ± 0
	MxH	2	3–24	13.5 ± 10.53
	BH	1	14	14 ± 0
	HH	1	42	42 ± 0
	FH	2	9–11	10 ± 1.00
Winter 2017–18 (December–February)				
	LTM	2	1	1 ± 0
	MxH	2	7–52	29.5 ± 15.05
	BH	5	3–11	7.4 ± 1.33
	HH	5	13–53	30.4 ± 7.19
	FH	1	21	21 ± 0
Annual 2017–18		**68**	**2–58**	**13.84 ± 1.89**

LTM—lone territorial male | UM-UF—unimale-unifemale | MxH—mixed herd | BH—bachelor herd | HH—harem herd | FH—female herd.

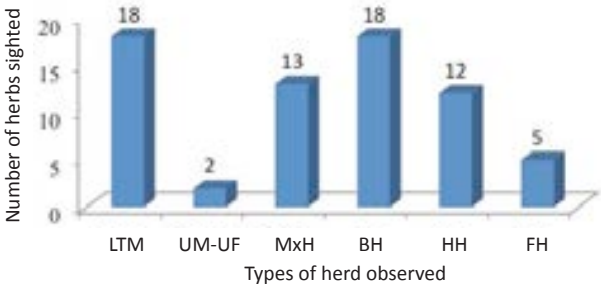

Figure 3. Variation in sighting of different types of herds of Blackbuck recorded in and around Lalpur Jheel, Dobhi Village from March 2017 to February 2018. LTM—lone territorial male | UM-UF—unimale-unifemale | MxH—mixed herd | BH—bachelor herd | HH—harem herd | FH—female herd.

DISCUSSION

Mammalian herbivores, especially ungulates, form groups that are effectively conspicuous in the field. There are two principle rationales regarding the group-behaviour of ungulates. The first proposes that when in groups the animals can counteract or maintain a strategic distance from the predators as compared to when they are alone and this could be possible through an assortment of strategies including predator recognition, active group defense and predator perplexity (Hamilton 1971; Wirtze & Lorscher 1983). Alternative rationale connects the animal's social organization with the dispersion and accessibility of its resource supply (Jarman 1974). According to previous studies, Blackbucks were seen both solitary and in groups reflecting their partial social organization. This is also seen in the present study. Ranjitsinh (1989) recorded six different types of social grouping of Blackbuck including solitary female, solitary male, a female with one or two offspring, females and young-groups, bachelor herd, and mixed herd involving harem herd also. Isvaran

Table 5. Group size and sex ratio of Blackbuck *Antilope cervicapra* (Linnaeus, 1758) from protected areas of India.

Study site	Group size	Adult male: adult female	Source
Lalpur Jheel, Haryana	2–58	0.25: 1	Present study
Mudmal Village, Andhra Pradesh	2–36	1: 2.47	Prasad 1983
Point Calimere Sanctuary, Tamil Nadu	2–129	1: 4.7	Nair 1976
Proposed Community Reserve for Blackbuck, Ganjam District, Odisha	2–32	1: 1.51	Mahato et al. 2010
Balipadar-Bhetnoi Blackbuck Conservation Area, Odisha	1–51	1: 3	Debata 2017
M.C. Zoological Park, Chhatbir, Punjab	10–25	-	Vats & Bhardwaj 2009a
Sorsan Grassland, Baran District, Rajasthan	4–100	-	Meena & Chourasia 2018
Tal Chappar Blackbuck Sanctuary, Rajasthan	-	1: 1.29	Dookia et al. 2011
Pipli Deer Park, Kurukshetra	8–25	-	Gupta & Bhardwaj 1990

(2007) reported three different types of herd sightings in Blackbuck namely; all male groups, female groups, and mixed-sex groups. During the present study, in the total 68 sightings of Blackbuck, six different types of social organization were observed including lone territorial male, unimale-unifemale, mixed, bachelor, harem, and female herds. The occurrence of different types of social organization was due to the seasonal variation in the distribution and availability of food resources (Jarman 1974). Habitat structure, predation pressure and resource availability are the main ecological factors responsible for the formation of groups (Lott 1991; Brashares & Arcese 2002) while the group size is mainly determined by habitat characteristics as it increases with open habitat and decreases with forested habitat (Leuthold 1970; Lagory 1986). In Lalpur jheel, the largest herd of 58 individuals was sighted in fallow land i.e. open habitat which confirms with Ranjitsinh (1982) and Barucha & Asher (1993) as they also recorded the larger groups of Blackbuck in open habitat comprising 430 and 200 individuals in Velavadar National Park and Rehukari Wildlife Sanctuary, respectively. Predation pressure was not very important in the study area due to the absence of large carnivores, as ascertained during our periodic visits. One of the major threats emerging to the Blackbuck population is the rise of feral dog population which was also reported by Gehlot & Jakher (2007). They found that 45% mortality in the Blackbuck population is caused by feral dogs. Along with habitat structure and predation pressure, resource availability is also one of the major factors which affect the group size in ungulate population. When resources are distributed in relatively small and distant areas then it favors small group sizes because in large group size the cost of competing for food surpasses any possible benefits (Chapman et al. 1995). The mean group size of Blackbuck population calculated as per the present study was 13.84 ± 1.89 and the group size range was 2–58 which was in accordance with the previous studies from different parts of India (Table 5). The mean group size parameter is beneficial only when there is normal distribution of organisms in a particular area, but during recent times clumped distribution is observed which makes the crowding phenomenon to be useful for the studies. Similar studies based on crowding phenomenon had been reported for megaherbivores, however, no such studies have been conducted on the Blackbuck (Ramesh et al. 2012b). The highest mean crowding value was recorded during the summer season because of scarcity of food resources in the study area. This favours formation of many small herds and only a few large herds. The crowding value increased as calculated according to Reiczigel et al. (2008). Fawning period in Blackbuck in Lalpur Jheel indicates that there was no distinct seasonality but two peaks were observed, the first during the summer season and second during the autumn season which is in consonance with observations by Schaller (1967), who reported the two peaks of fawning in March–April and August–October in Kanha National Park. The adult-male: adult-female ratio from the study area was low as compared to previous studies as shown in Table 5, which may be due to the hunting of adult males for its meat and horns which were further used in Ayurveda and to cure skin diseases. A positive side of this skewed sex ratio is that a population with more females than males has a higher reproductive potential than the one which is predominately composed of males (Spillet 1966) because the adult female: fawn ratio had increased, i.e., 6.70: 1 which was high as compared to the other study as in the proposed community reserve for Blackbuck, Ganjam District, Odisha, India (Mahato et al. 2010).

The major threats to Blackbuck population are

Image 1. Different types of herds recorded during periodic visits at Lalpur Jheel, Dobhi Village, Hisar: a—lone territorial male | b—unimale-unifemale | c—bachelor herd | d—harem herd | e—mixed herd | f—female herd. © Jyoti.

habitat loss, human-Blackbuck interaction, competition with livestock, predation pressure from fox, road kill and killing by feral dogs that decreases the overall population size in comparison to the status in past decades in Sorsan grassland, Rajasthan, India (Meena & Chourasia 2018). In the present study there were many factors responsible for limited sightings of Blackbuck in the study area including fragmentation of habitat through the construction of a concrete road, movement of vehicles, encroachment by cattle and increased feral dog population, as reported by Gehlot & Jakher (2007) in the Thar Desert of Rajasthan. This study area requires regular monitoring and effective conservation strategies as viable population of Blackbuck were reported both through fortnightly periodic visits as well as opinion survey findings.

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An updated checklist of Indian western Himalayan gymnosperms and lectotypification of three names

Jibankumar Singh Khuraijam [1] & Jaideep Mazumdar [2]

[1] Botanic Garden Division, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow, Uttar Pradesh 226001, India.
[2] Department of Biological Sciences, Burdwan Town School, Burdwan, West Bengal 713101, India.
[1] jskhuraijam@yahoo.com (corresponding author), [2] jaideepmazumdar10@gmail.com

Abstract: An updated checklist of gymnosperms of the western Himalaya situated within political boundaries in India is provided along with conservation status and distribution. Lectotype for three names viz., *Cedrus deodara* (Roxb. ex Lam.) G. Don, *Pinus roxburghii* Sarg., *Picea smithiana* (Wall.) Boiss. are designated.

Keywords: Conservation status, distribution, habitats, herbarium studies, Himalayan region.

Living gymnosperms comprise four distinct lineages, *Ginkgo* K.Richt. (1 sp.), gnetophytes (112 spp.), cycads (355 spp.), and conifers (638 spp.) (Calonje et al. 2019; WCSP 2019). Members of gnetophytes are distributed in a wide range of vegetation ranging from desert to cold desert at high elevations while cycads are confined mainly to the tropical regions. Centres of cycad diversity occur in southern Africa, Australia, and the tropical New World (Donaldson et al. 2003). Conifers tend to dominate forests in the northern hemisphere and have a rich and diverse existence in the southern hemisphere, but are reduced in numbers in most tropical environments (Conway 2013).

In southern Asia, gymnosperms are mostly confined to the Himalayan region. Conifers and *Ephedra* L. are found in the temperate and alpine region along the entire stretch of the Himalaya while tropical gymnosperms, namely, *Cycas* L. and *Gnetum* L., grow naturally in peninsular and northeastern India, Nepal, Bangladesh and Bhutan. In the unfinished series on gymnosperms of western Himalaya, Dar & Christensen (2003) reported seven taxa of *Juniperus,* and Srivastava (2006) listed 101 taxa (indigenous and exotic) of gymnosperms from India. Singh & Srivastava (2013) revised the checklist and reported the occurrence of 146 species and seven varieties of gymnosperms in India with extensive details of exotic/introduced species. Rana & Rawat (2017) established a database of Himalayan plants which enlisted 51 species of gymnosperms belonging to eight families and 20 genera from the Himalayan region of India, Nepal and Bhutan. Singh et al. (2018) reported 88 species of gymnosperms in the Himalayan Biodiversity Hotspot.

The Indian western Himalaya consist of three states namely Jammu & Kashmir, Himachal Pradesh and Uttarakhand. Recently, nine species and one variety of *Ephedra* were described from these states out of which five taxa were not effectively published (Sharma & Uniyal

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2009; Sharma et al. 2010; Sharma & Singh 2015, 2016; Sharma et al. 2015). The latest addition of conifers in the western Himalaya is *Juniperus chinensis* L. which was reported from Jammu & Kashmir (Singh et al. 2018). The species is previously reported to be an introduced species in India (Sood et al. 2010; Singh & Srivastava 2013).

Materials and Methods

Herbarium studies at Forest Research Institute, Dehradun (DD), Botanical Survey of India, Northern Regional Centre, Dehradun (BSD), National Botanical Research Institute, Lucknow (LWG), Botanical Survey of India, Howrah (CAL) and consultation of literature and virtual specimens available online at Royal Botanic Gardens, Kew (K), University of Copenhagen, Copenhagen (C), Muséum National d'Histoire Naturelle, Paris (P), Botanischer Garten und Botanisches Museum Berlin-Dahlem (B), Meise Botanic Garden, Meise (BR), and Royal Botanic Garden Edinburgh (E) provided significant information for the current investigation. While making the checklist, we followed linear sequence of extant gymnosperms by Christenhusz et al. (2011) and exotic or introduced species were excluded.

The names of three species of gymnosperms of the western Himalaya required typification since the authors had either not designated a type or designated ambiguous specimens. In order to understand these treatments, all the protologues of the published taxa were studied.

The checklist

The checklist is the updated enumeration of gymnosperms of the Indian western Himalaya. Thirty species, one subspecies and two varieties belonging to nine genera of gymnosperms are enlisted along with their distribution and current conservation status (Tables 1, 2). The present checklist will serve as a base for future research on gymnosperms in the region.

Two species of *Juniperus*, namely, *polycarpos* and *macropoda*, which were listed in the previous checklists of Indian gymnosperms by Singh & Srivastava (2013) and Srivastava (2006), are now considered synonyms of *Juniperus excelsa* subsp. *polycarpos* (K. Koch) Takht. (Farjon 2017). Hence, the subspecies is incorporated in the present checklist. Likewise, *Juniperus wallichiana* which was listed in Srivastava (2006), is now considered to be a synonym of *Juniperus indica* (Farjon 2017).

Sharma et al. (2011) based on molecular studies recognized five taxa of *Ephedra* from the western Himalaya, namely, *Ephedra yurtungensis* Sharma &

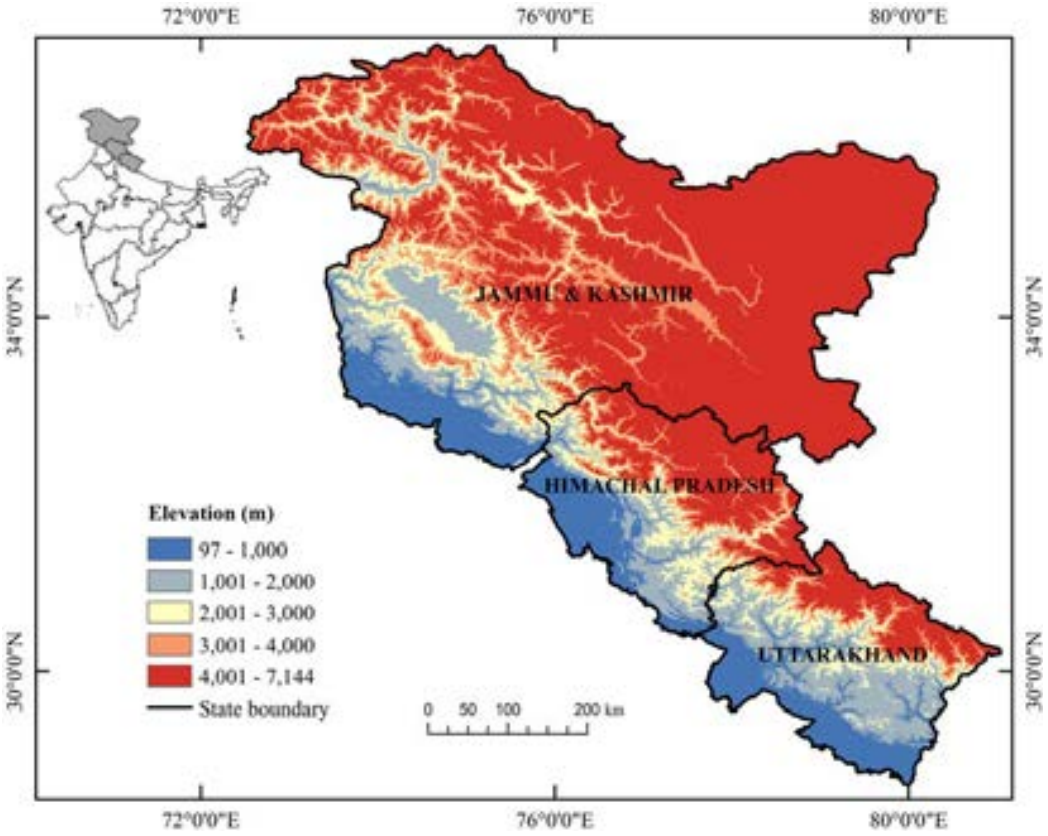

Figure 1. The Indian western Himalaya.

Uniyal, *E. yurtungensis* var. *lutea* Sharma & Uniyal, *E. lamayuruensis* Sharma & Uniyal, *E. sheyensis* Sharma & Uniyal, *E. khardongensis* Sharma & Uniyal. However, they were not published effectively as they did not fulfill criteria (Art. 38 to 40) (Turland et al. 2018) and hence excluded from this study.

Typification

1. *Pinus roxburghii* Sarg. (1897: 9) nom. nov. [Pinaceae]

Pinus longifolia Roxb. ex Lam. (1803: 29, t. 21) nom. illeg. non Salisb. (1796: 398).

Type (lectotype, designated here): Lambert (1803), Descr. Pinus 1: Tab. XXI "Pinus longifolia" [Icon]. (Fig. 1).

Note: Lambert (1803) validated *Pinus longifolia* Roxb. with description and illustration in his book "A description of the genus *Pinus*"; however, *Pinus longifolia* Roxb. ex Lamb. (1803) proved an illegitimate later homonym of *Pinus longifolia* Salisb. (1796). Sargent (1897), therefore, proposed the replacement name (nom. nov.) *Pinus roxburghii* Sarg. for *Pinus longifolia* Roxb. ex Lamb., in honour of Dr. William Roxburgh, the collector of this specimen.

The name *Pinus roxburghii* Sarg. is based on Roxburgh's collection from the mountains of Nepal and "Indie orientalis" (an old term including the Indian subcontinent).

Farjon (2017) mentioned that holotype was not located and isotype was stored in B-W. A Roxburgh specimen exists in Herb. Willdenow (BW17762010). This specimen is composed of needles and a part of shoot. This specimen was collected by Roxburgh and locality is mentioned on the back side of this sheet as India ("Habitat in India"). It carries annotations "Pinus longifolia (Roxburgh)" and "P. longifolia 1".

Another Roxburgh specimen (only needles) exists in BR (BR0000013468941) collected by Roxburgh. Locality not mentioned, but it carries an annotation "Pinus longifolia".

Similar annotations indicate that both specimens were in possession of Roxburgh. As Lambert (1803) did not mention any "Type" or "Holotype", specimens in B and BR are syntypes (Turland et al. 2018, Art. 9.6).

After the death of Lambert his herbarium was sold in parts and dispersed in many herbaria (see details in Miller 1970). It is not clear that these Roxburgh specimens at B and BR were from Lambert's herbarium and represent original material. To avoid any conflict in future we conservatively select Lambert's illustration Tab. 21 "Pinus longifolia" as lectotype which is also an original material (Turland et al. 2018, Art. 9.4.b).

Volumes and editions of Lambert's "A description of the genus *Pinus*" has some errors during printing and binding as noted by Renkema & Ardagh (1930) and Little (1949). There is an additional plate of Tab. 21 of "Pinus longifolia" (Renkema & Ardagh 1930: 443) and we select one of them (Image 2).

2. *Cedrus deodara* (Roxb. ex Lam.) G. Don (1830: 388) [Pinaceae]

Pinus deodara Roxb. ex Lambert (1824: 8); *Cedrus libani* A. Rich. subsp. *deodara* (Lambert) P.D. Sell (1990: 92).

Type (lectotype, designated here): Lambert (1824), Descr. Pinus 2: Tab. "Pinus Deodara" [Icon]. Image 3.

Note: Lambert (1824) published *Pinus deodara* in his highly acclaimed book "A description of the genus *Pinus*" and in the protologue he cited Dr. William Roxburgh's unpublished name "Pinus Deodar. Roxb. Fl. Ind. ined." and also mentioned locality "Habitat in Indiae Orientalis montibus ad urbis Rohilcund Septentrionem. Roxburgh." "Rohilcund" is now a region in Uttar Pradesh, India.

Farjon (2017) mentioned that type was not designated for *Pinus deodara*. We located a Roxburgh specimen in BR (BR0000013468958) carrying annotations "Pinus Deodara Roxb. male" and "Herb. Roxburghii" indicating that it was once in the possession of Roxburgh.

As mentioned above, after the death of Lambert his herbarium was sold in parts and dispersed in many herbaria (Miller 1970). It is not clear that BR0000013468958 is the same specimen which Lambert studied, that is, original material. Selection of BR0000013468958 may warrant further changes in future. Thus we conservatively select Lambert's unnumbered Tab. "Pinus Deodara" (Image 1) as lectotype which is definitely studied by Lambert and original material (Turland et al. 2018, Art. 9.4.b).

3. ***Picea smithiana*** (Wall.) Boiss. Fl. Orient. [Boissier] 5(2): 700. 1884 [Pinaceae]

Pinus smithiana Wall. Plantae Asiaticae Rariores 3: 24, t. 246. 1832.

Type (lectotype, designated here):—Himalayas: Webb, Govan & Blinkworth, Catalogue no. 6063 (K001122925 [image]!). Image 4.

Note: Wallich (1832a) in his Numerical list first introduced the name *Pinus smithiana* Wall., but without any description (nom. nud.) and not validly published (Turlad et al. 2018, Art. 38, Ex. 1). Later Wallich (1832b) validated *Pinus smithiana* in third volume of *Plantae Asiaticae rariores*, with description and a colour plate "Tab. 246" which is the original material for this name (Turland et al. 2018, Art. 9.4). As mentioned by Wallich,

Image 1. A - Coniferous forest in the western Himalaya | B - *Cedrus deodara* habit | C - *Picea smithiana* | D - *Cedrus deodara* | E - *Pinus wallichiana* | F - *Cupressus torulosa*. © J.S. Khuraijam.

Table 1. Checklist of extant gymnosperms of the Indian western Himalaya.

	Taxa	Distribution in Indian western Himalaya	Global distribution	Conservation status (IUCN 2019)
Subclass: Gnetidae Order: Ephedrales Family: Ephedraceae				
1	*Ephedra gerardiana* Wall. ex Klotzsch & Garcke	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, China, Nepal, Pakistan, Tajikistan	Not Evaluated
2	*Ephedra intermedia* Schrenk & C.A.Mey.	Himachal Pradesh, Jammu & Kashmir	Afghanistan, China, Iran, Islamic Republic of Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan, Russia, Tajikistan, Turkmenistan, Uzbekistan	Least Concern
3	*Ephedra kardangensis* P.Sharma & P.L.Uniyal	Himachal Pradesh	-	Least Concern
4	*Ephedra khurikensis* P.Sharma & P.L.Uniyal	Himachal Pradesh	-	Data Deficient
5	*Ephedra major* Host	Himachal Pradesh, Jammu & Kashmir	Afghanistan, Albania, Algeria, Bosnia and Herzegovina, Cyprus, France, Greece, Iran, Italy, Lebanon, Morocco, Pakistan, Spain, Syria, Tunisia, Turkey, Turkmenistan	Least Concern
6	*Ephedra pachyclada* Boiss.	Jammu & Kashmir	Pakistan, Nepal	Least Concern
7	*Ephedra pangiensis* Rita Singh & P.Sharma	Himachal Pradesh	-	Not Evaluated
8	*Ephedra przewalskii* Stapf	Jammu & Kashmir	China, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, Tajikistan, Uzbekistan	Least Concern
9	*Ephedra regeliana* Florin	Jammu & Kashmir	Afghanistan, China, Kazakhstan, Kyrgyzstan, Pakistan, Russia, Tajikistan, Uzbekistan	Least Concern
10	*Ephedra saxatilis* (Stapf) Royle ex Florin	Himachal Pradesh, Uttarakhand	China, Nepal	Least Concern
11	*Ephedra sumlingensis* P.Sharma & P.L.Uniyal	Himachal Pradesh	-	Not Evaluated
12	*Ephedra yangthangensis* P.Sharma & Rita Singh	Himachal Pradesh	-	Not Evaluated
Subclass: Pinidae Order: Pinales Family: Pinaceae				
13	*Cedrus deodara* (Roxb. ex Lambert) G.Don	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, Pakistan, China, Nepal	Least Concern
14	*Pinus gerardiana* Wall. ex D.Don	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, Pakistan, China	Near Threatened
15	*Pinus roxburghii* Sarg.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Pakistan, China, Nepal, Bhutan	Least Concern
16	*Pinus wallichiana* A.B.Jacks.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, Pakistan, China	Least Concern
17	*Picea smithiana* (Wall.) Boiss.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, China, Nepal	Least Concern
18	*Tsuga dumosa* (D. Don) Eichler	Uttarakhand	China, Nepal, Bhutan, Myanmar, Vietnam	Least Concern
19	*Abies pindrow* (Royle ex D.Don) Royle	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, Nepal, Pakistan,	Least Concern
20	*Abies pindrow* var. *brevifolia* Dallim. & A.B.Jacks.	Jammu & Kashmir, Uttarakhand	-	Data Deficient
21	*Abies spectabilis* (D.Don) Mirb.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, China, Nepal	Near Threatened
Order: Cupressales Family: Cupressaceae				
22	*Cupressus torulosa* D. Don ex Lamb.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	China, Nepal, Bhutan	Least Concern
23	*Juniperus chinensis* L.	Jammu & Kashmir	China, Myanmar, Taiwan, Japan, Korea, Russia	Least Concern
24	*Juniperus communis* L.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	United States, Canada, Europe, central Asia, eastern Asia	Least Concern
25	*Juniperus communis* var. *saxatilis* Pall.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Europe, Caucasus, Siberia, central Asia, western Asia, Pakistan, Nepal, China, eastern Asia, East Russia, Canada, United States of America	Not evaluated

	Taxa	Distribution in Indian western Himalaya	Global distribution	Conservation status (IUCN 2019)
26	*Juniperus indica* Bertol. (Syn.: *Juniperus wallichiana* Hook. f. & Thomson ex Parl.)	Uttarakhand	China, Nepal, Bhutan	Least Concern
27	*Juniperus excelsa* subsp. *polycarpos* (K. Koch) Takht. (Syn.: *Juniperus polycarpos* K.Koch, *Juniperus macropoda* Boiss)	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Iran, Turkey, Oman, Afghanistan, Pakistan	Least Concern
28	*Juniperus pseudosabina* Fisch. et C.A. Mey	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Uzbekistan, Pakistan	Least Concern
29	*Juniperus recurva* Buch.-Ham. ex D. Don	Himachal Pradesh, Uttarakhand	Afghanistan, Bhutan, China, Myanmar, Nepal, Pakistan	Least Concern
30	*Juniperus semiglobosa* Regel	Jammu & Kashmir, Uttarakhand	Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Afghanistan, China	Least Concern
31	*Juniperus squamata* Buch.-Ham. ex D. Don	Jammu & Kashmir, Uttarakhand	Afghanistan, China, Taiwan	Least Concern
Family: Taxaceae				
32	*Taxus contorta* Griff.	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Afghanistan, Pakistan, China, Nepal	Endangered
33	*Taxus wallichiana* Zucc.	Uttarakhand	Bhutan, China, Indonesia, Myanmar, Nepal, Pakistan, Philippines, Vietnam	Endangered

Sources: Sahni 1990; Singh & Mudgal 1997; Dogra 1999; Dar & Christensen 2003; Dar & Dar 2006; Srivastava 2006; Eckenwalder 2009; Farjon 2010, 2017; Singh & Srivastava 2013; Sharma & Singh 2015, 2016; Singh et al. 2018a, 2018b.

Image 2. Lectotype of *Pinus roxburghii*: Lambert's Tab. XXI "Pinus longifolia".

Image 3. Lectotype of *Cedrus deodara*: Lambert's Tab. "Pinus Deodara".

Image 4. Lectotype of *Picea smithiana* (Wall.) Boiss. (K, K001122925!) © The Board of Trustees of the Royal Botanic Gardens, Kew. Reproduced with the consent of the Royal Botanic Gardens, Kew.

the epithet *smithiana* is dedicated to botanist Sir James Edward Smith (1759–1828), founder and president (during 1788–1828) of the Linnean Society, London (Stafleu & Cowan 1985).

In the protologue of *Pinus smithiana*, Wallich mentioned the locality as mountains of the Himalaya and collectors Webb, Govan and Blinkworth. Wallich's name was based on specimens "Catalogue no. 6063". Christensen & Orlova (2006) located the specimen Webb & Govan 6063 at C and designated it as lectotype. We searched for the lectotype of *Picea smithiana* at C for examination. But this lectotype was lost from C and we could not locate it at any other herbaria.

Although Christensen & Orlova (2006) did not mention about any other type specimens of *Pinus smithiana* elsewhere, collection of Webb, Govan & Blinkworth, no. 6063 exists in Herb. Wallich at K (barcode K001122925). Art. 9.11 (Turland et al. 2018) permits selection of another lectotype when previously designated lectotype is lost or destroyed. We select specimen at K (original material) as lectotype of *Pinus smithiana*.

Table 2. Native gymnosperms of the Indian western Himalaya.

	Genera	Species	Subspecies	Variety
1	*Ephedra*	12	-	-
2	*Cedrus*	1	-	-
3	*Pinus*	3	-	-
4	*Picea*	1	-	-
5	*Tsuga*	1	-	-
6	*Abies*	2	-	1
7	*Cupressus*	1	-	-
8	*Juniperus*	7	1	1
9	*Taxus*	2	-	-
Total	**9**	**30**	**1**	**2**

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New record of Blue Perch *Badis badis* (Anabantiformes: Badidae) from Godavari River basin of Telangana State, India

Kante Krishna Prasad [1] & **Chelmala Srinivasulu** [2]

[1,2] Natural History Museum and Wildlife Biology & Taxonomy Lab, Department of Zoology, University College of Science, Osmania University, Hyderabad, Telangana 500007, India.
[2] Systematics, Ecology & Conservation Laboratory, Zoo Outreach Organization, No. 12 Thiruvannamalai Nagar, Saravanampatti, Coimbatore, Tamil Nadu 641035, India.
[1] kpmanjeera@gmail.com, [2] chelmalasrinivasulu@gmail.com (corresponding author)

Abstract: *Badis badis* (Hamilton, 1822), a freshwater fish species, has been reported for the first time from the Godavari River basin of Telangana State, India. One specimen of *B. badis* was collected from a stream near Mubarakpur Village in Sangareddy District (Manjeera sub-basin) and another from a stream near Sirpur (T) Town in Asifabad District (Wardha sub-basin), Telangana State, India. This publication provides information about *B. badis* occurrence in India, a short description of the collected specimen, and a discussion on its habitat and threats.

Keywords: Asifabad, Chameleon Fish, freshwater fish, Manjeera River, Percomorpha, Sangareddy, Wardha River.

Badis badis (Hamilton, 1822) is a freshwater fish which exhibits remarkable colour patterns on its body with blue iridescent marks on the fins. Due to its attractive and colourful pattern, it is used as an ornamental fish species and exploited in the aquarium trade (Gupta et al. 2016). This fish belongs to the family Badidae and is commonly known as Blue Perch or Chameleon Fish. Badidae is distributed in southern Asia, from Pakistan to India, Bhutan, Bangladesh, China, Nepal, Myanmar, and Thailand (Kullander & Britz 2002; Schindler & Linke 2010; Britz & Kullander 2013; Froese & Pauly 2018). Globally, Badidae comprises of two genera, namely *Badis* (22 species) and *Dario* (seven species) (Kullander & Britz 2002; Fricke et al. 2018; Froese & Pauly 2018). In India, members of Badidae are distributed in the river basins of the Ganges in Uttar Pradesh and West Bengal, Yamuna in Himachal Pradesh, Brahmaputra in Assam and Arunachal Pradesh (Menon 1999; Geetakumari & Kadu 2011; Valdesalici & van der Voort 2015), Meghna in Meghalaya (Britz & Kullander 2013), Tuivai in Manipur (Vishwanath & Shanta 2004), Mahanadi in Odisha (Menon 1999; Jayaram 2010), Godavari in Chhattisgarh (Karmakar & Datta 1998) and Madhya Pradesh (Yadav 2005, 2006), Tunga (Britz & Ali 2015) and Sharavati in Karnataka (Dahanukar et al. 2015), and Penna (Chembarampakkam Tank) in Tamil Nadu (Knight & Devi 2009).

A few records are available regarding the distribution of *B. badis* in peninsular India, namely in the Godavari River basin of Maharashtra (Day 1878), Chhattisgarh (Karmakar & Datta 1998), and Madhya Pradesh (Yadav 2005, 2006), the Mahanadi River basin in Odisha (Menon 1999), the Pennar River basin in Tamil Nadu (Knight & Devi 2009), and the Tungabhadra River basin in Karnataka (Dahanukar et al. 2015). Devi & Indra (2003) reported this species from the

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Eastern Ghats, but the exact location is not known. In this paper, we report the occurrence of *B. badis* for the first time in the Manjeera and Wardha sub-basins of the Godavari River basin in Telangana State, India.

Material and Methods

We followed random sampling during the surveys conducted in the streams across the Sangareddy and Asifabad districts, Telangana, to study fish diversity. Fish were collected using cast nets with the help of fishermen. Collected specimens were photographed, labelled, and preserved in 4% formalin. Meristic and morphometric measurements were taken following Jayaram (2010) and Armbruster (2012). Morphometric measurements were taken point to point to the nearest 0.1mm using Mitutoyo digital callipers. Morphometric values, except the total, standard, and head length, were expressed in percentage of the standard length of the fish. Additionally, subunits of the head were expressed as percentage of head length. Identification of the fishes was done based on Kullander & Britz (2002), Jayaram (2010), and Froese & Pauly (2018). Specimens (NHM.OU.F-26-2015 and NHM.OU.F-01-2017) were deposited in the Natural History Museum, Osmania University, Hyderabad, India.

Result

We collected two specimens of *B. badis* from Telangana, India (Fig. 1).

Genus *Badis* Bleeker, 1853

Badis badis (Hamilton, 1822)

Materials examined: Telangana State, India: NHM.OU.F-26-2015, 13.x.2015, stream near Sirpur-(T) Town, Wardha sub-basin, Asifabad District, 19.484^{0}N & 79.594^{0}E, 161m, coll. Kante Krishna Prasad, Gundena Devender & Gandla Chethan Kumar; NHM.OU.F-01-2017, 28.iv.2017, stream near Mubarakpur Village, Manjeera sub-basin, Sangareddy District, 17.639^{0}N & 78.023^{0}E, 508m, coll. Kante Krishna Prasad & Hyderaboni Laxman.

Distinguishing characters: *Badis badis* is distinguished from its other congeners in the combination of the following characters: body moderately elongated in shape, compressed on the lateral sides; vertical bars on lateral side; abdomen rounded. Head large, laterally compressed; snout blunt. Specific dark blotch on superficial part of cleithrum; operculum with one sharp spine; a small blue spot rounded by a black ring on each shoulder; base of the scales shine silver. Scales of moderate size, ctenoid. Lateral line incomplete; lateral line runs unto the posterior of dorsal fin; lateral line row scales 28. Dorsal fin with 16–18 hard spines and 7–8 branched rays, prominent black blotches along dorsal fin base, and middle with narrow white edge. Pectoral fins with one soft ray and 10 branched rays; pelvic fin with one hard ray and five branched rays. Anal fin with three spines and six branched rays. Caudal fin rounded. Detailed morphometric measurements, ratios, and meristic counts are presented in Table 1.

Habitat: At Sirpur, a lone specimen of *B. badis* (Image 1A) was collected in a stream consisting of submerged boulders and small pebbles with sand silt as substratum. The riparian vegetation on both sides of the stream was dominated by Pink Morning Glory *Ipomoea* sp. and Lesser Cattail *Typha* sp. The stream was polluted with organic waste dumped through sewer lines from a nearby village. The species was collected from a ditch in the streambed with Water Thyme *Hydrilla* sp. and Tape Grass *Vallisneria* sp. The place where the species was captured was in the shadow of riparian vegetation. In the stream, *Laubuka laubuca* (Hamilton, 1822), *Pethia ticto* (Hamilton, 1822), *Puntius chola* (Hamilton, 1822), and *Systomus sarana* (Hamilton, 1822) were observed.

At Mubarakpur, another lone specimen of *B. badis* (Image 1B) was collected in a stream with sand silt as substratum and dominated by emergent vegetation of Water Thyme *Hydrilla* sp., Water Lily *Nymphaea* sp., Lotus *Nelumbo* sp., Water Cabbage *Pistia*, Dense Flower Knotweed *Polygonum* sp., and Tape Grass *Vallisneria* sp. The riparian vegetation included Babool *Acacia* sp., Pink Morning Glory *Ipomoea* sp., Algaroba *Prosopis* sp., and Lesser Cattail *Typha* sp. on both the banks. This species shared its habitat with *Esomus danrica* (Hamilton, 1822), *Pethia ticto* (Hamilton, 1822), *Pseudambassis lala* (Hamilton, 1822), *Puntius chola* (Hamilton, 1822), and *P. sophore* (Hamilton, 1822).

Habitat loss due to sand mining and pollution due to organic wastes from sewers were the major threats to *B. badis* at Sirpur, Wardha sub-basin; no threat was observed at Mubarakpur of Manjeera sub-basin.

Discussion

Badis badis originally described as *Labrus badis* from the lowlands of the Ganges and Brahmaputra drainages in northeastern India by Hamilton (1822). Later, it was reported by Day (1878) from Bombay and Madras presidencies (which also includes the states of Andhra Pradesh, Karnataka, Kerala, Orissa, and Tamil Nadu) without proper location information. Although *B. badis* was recorded in peninsular India (Karmakar & Datta 1998; Menon 1999; Devi & Indra 2003; Yadav 2005, 2006; Knight & Devi 2009; Dahanukar et al. 2015), the exact localities were not provided by most workers. The Telugu vernacular name 'Kundala' or 'Ka-sundara' for this fish was first provided by Day (1878) in his works from Bombay and Madras presidencies. Until now,

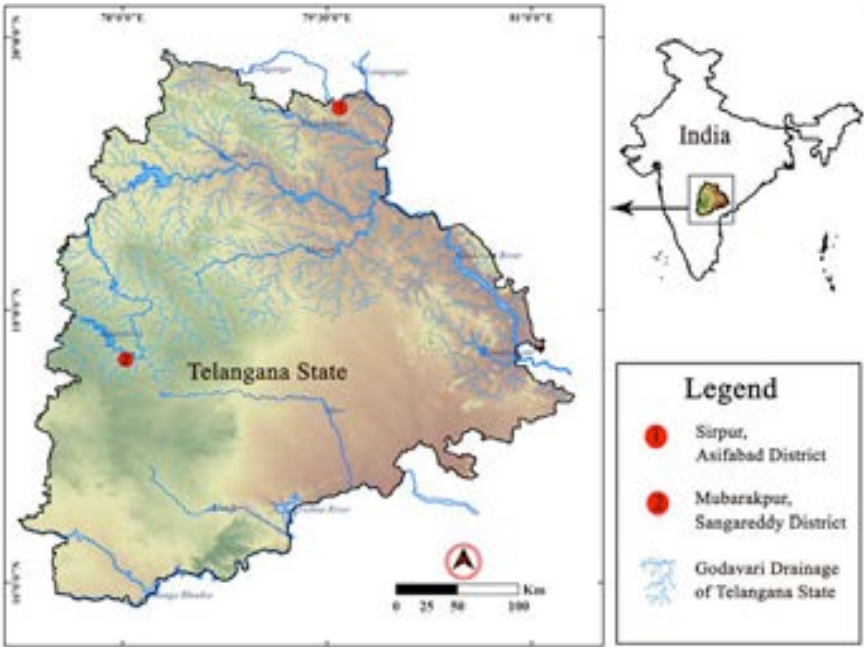

Figure 1. Distribution of *Badis badis* in Godavari basin of Telangana State, India.

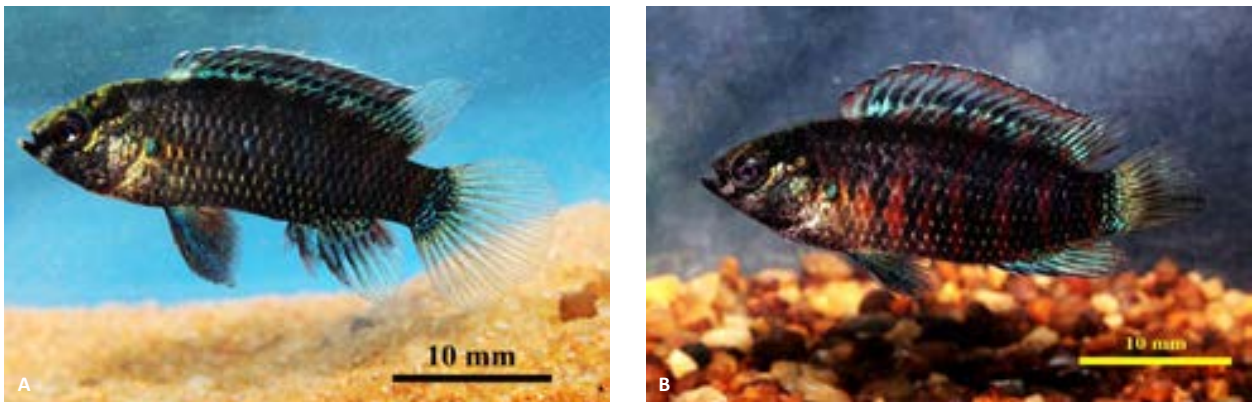

Image 1 . *Badis badis* (Hamilton, 1822)—color variation: A - from Wardha River basin (collected in a stream polluted with organic waste) | B - from Manjeera River basin (collected in a stream with clear water). © Kante Krishna Prasad.

the exact locality record of *B. badis* in erstwhile Andhra Pradesh is lacking. This fish was not reported by earlier workers, though Barman (1993) opined that this may occur in the Telangana region of Andhra Pradesh. This may have been due to its solitary nature and behaviour of hiding in aquatic vegetation. Knight & Devi (2009) also expressed the same opinion about this fish in Tamil Nadu. We too noticed this behaviour in both areas.

We noticed the colour variation of this species in both clear water and polluted water (Image 1). The fish captured in the stream polluted with organic waste at Wardha River sub-basin (Image 1A) showed dirty red and black coloured vertical bands amalgamated on the lateral side of the body. Its overall appearance was black with blue iridescence on the fins. On the other hand, the fish captured in the stream with clear water at Manjeera River sub-basin (Image 1B) showed a bright red-coloured body with six black vertical bands alternatively on the lateral sides. Earlier, Day (1878) too reported a similar colour variation in the species in clear and dirty waters. The specimens from Telangana differed from the earlier report from southern India, particularly from Tamil Nadu, with respect to the circumpeduncular scale count (16 vs. 19–20; Knight & Devi 2009).

The occurrence of *B. badis* in the Manjeera and Wardha sub-basins of the Godavari River reveals that this species could be more widespread than currently known. There is a need for the study of the distribution and population trend of this species (Chaudhry 2010) to enrich scientific knowledge and to understand its threat status.

Table 1. Morphometric characters and meristic counts of *Badis badis* from Wardha and Manjeera sub-basins, Telangana State, India.

Morphometric characters	Specimen voucher NHM.OU.F-26-2015	Specimen voucher NHM.OU.F-01-2017
Total length (mm)	34.3	36.3
Standard length (SL, mm)	27.9	28.9
Head length (HL, mm)	7.6	8.0
% of SL		
Body depth	31.2	35.3
Head length	27.5	27.7
Head depth	22.4	24.6
Head width	13.7	14.6
Eye diameter	11.2	9.8
Snout length	4.5	5.0
Inter orbital width	8.0	7.9
Dorsal fin base length or dorsal fin width	57.4	56.6
Pre-dorsal distance	29.9	31.5
Dorsal fin length at branched rays	17.0	18.3
Dorsal fin spine length	11.7	18.9
Dorsal fin origin to hypural distance	70.2	70.8
Pectoral fin length	23.7	23.6
Pelvic fin length	24.8	26.2
Caudal peduncle length	18.6	16.3
Caudal peduncle depth	14.9	16.5
Pre pelvic distance	33.4	34.2
Pre anal distance	66.2	68.8
Anal fin base length	17.8	19.7
Anal fin length	30.1	34.5
% of HL		
Head depth	81.6	89.0
Head width	50.1	52.9
Eye diameter	40.7	35.4
Snout length	16.5	18.1
Inter orbital width	29.1	28.7
Meristic counts		
Lateral line row scales	28	28
Between lateral line and dorsal fin scales	3	3
Between lateral line and ventral fin scales	8	7
Between lateral line and anal fin scales	7	7
Transverse scale rows	11	10
Predorsal scales	8	7
Prepelvic scales	7	6
Preanal scales	21	20
Dorsal fin rays	XVI+8	XVII+7
Pectoral fin rays	i+10	i+10
Pelvic fin rays	I+5	I+5
Anal fin rays	III+6	III+6
Caudal fin rays (principal)	14	14
Caudal fin rays (procurrent)	6	6
Circumpeduncular scales	16	16

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First record of the Small Bamboo Bat *Tylonycteris fulvida* (Peters, 1872) (Mammalia: Chiroptera: Vespertilionidae) from Nepal

Basant Sharma [1], Anoj Subedi [2], Bandana Subedi [3], Shristee Panthee [4] & Pushpa Raj Acharya [5]

[1,4] Bat Friends Pokhara, Hariyokharka-15 Pokhara, Kaski, Nepal.
[1,5] Nepal Bat Research and Conservation Union (NeBRCU), Batulechour-16 Pokhara, Kaski, Nepal.
[1–4] Tribhuvan University, Institute of Forestry, Hariyokharka-15 Pokhara, Kaski, Nepal.
[5] Central Campus of Science and Technology, Faculty of Science, Mid-western University, Birendranagar, Surkhet, Nepal.
[1] b.s.sharma237@gmail.com (corresponding author), [2] anojsubedi99@gmail.com, [3] bandanasubedi84@gmail.com, [4] shristeesharma3@gmail.com, [5] armalepushpa@gmail.com

Abstract: A bamboo bat of the genus *Tylonycteris* was captured near Gupteshore Cave of Kushma in Parbat, Nepal. Traditionally, two species of *Tylonycteris* (of *T. pachypus* complex and *T. robustula* complex) are known from the Indian subcontinent. Due to inconsistency in taxonomic classification, several changes were recently made within the genus *Tylonycteris*—*T. pachypus* was corrected to *T. fulvida* and *T. robustula* to *T. malayana*. The occurrence of *Tylonycteris* from Nepal's diversified zoogeography, however, was never mentioned. This note provides a new record of *Tylonycteris* from Nepal. Based on morphological characteristics and species distribution range, this note confirms the captured species as *T. fulvida*.

Keywords: Gupteshore Cave, Kushma, new record, Parbat, *Tylonycteris*.

A total of 128 species of bats are reported from the Indian subcontinent, including 115 species of yangochiropterans and 13 species of yinpterochiropterans (Srinivasulu et al. 2010). Nepal records 53 species of bats within the families Pteropodidae (5), Rhinolophidae (9), Hipposideridae (4), Megadermatidae (1), Emballonuridae (1), Vespertilionidae (31), and Miniopteridae (2) (Acharya et al. 2010). The reported number of species represents the bat diversity of about 5% of the world and over 40% of southern Asia. Among these, two species are categorized as Critically Endangered, one as Endangered, two as Vulnerable, four as Near Threatened, 25 as Least Concern, and 19 as Data Deficient in the National Red List (Jnawali et al. 2011). Vespertilionidae is the most species-rich family with 58.5% of bat species from Nepal within 15 genera. *Myotis* (7) is the most species-rich genus within this family, followed by *Murina* (3) and *Pipistrellus* (3). There has been, however, no previous evidence of the genus *Tylonycteris* in Nepal.

Traditionally, *Tylonycteris* was classified as containing only two species: *T. pachypus* (Temminck, 1840) and *T. robustula* (Thomas, 1915). Several other taxa were included as subspecies within these two species groups (Simmons 2005). Later, Feng et al. (2008) described a third species, *T. pygmaea* (Feng, Li & Wang 2008), which is smaller than its congeners. It is endemic to the Yunnan Province in southern China, while the former two

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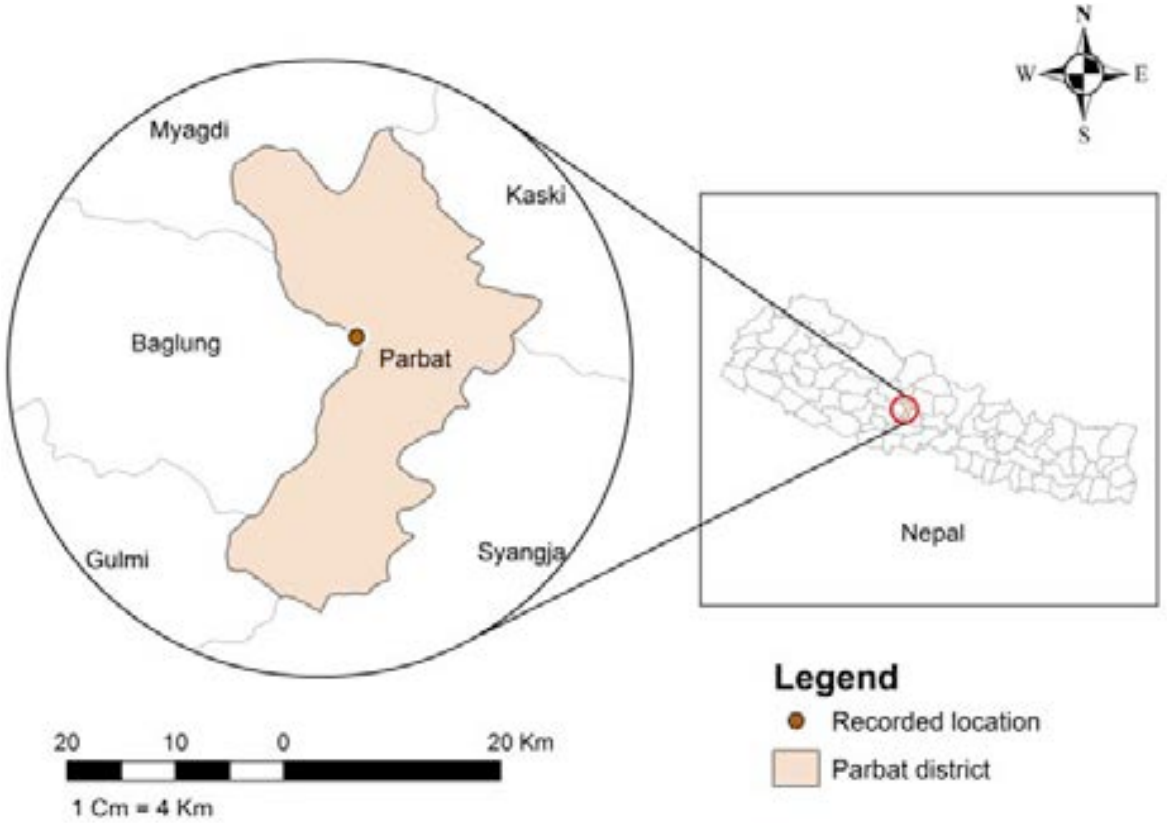

Figure 1. New record of *Tylonycteris fulvida* near Gupteshore Cave of Kushma, Parbat, Nepal.

species have much more extensive geographic ranges that greatly overlap in southeastern Asia (Tu et al. 2017). Due to inconsistency in taxonomic classification, Tu et al. (2017) recently revalidated several changes within *Tylonycteris*—*T. pachypus* was corrected to *T. fulvida* (Blyth, 1859) and *T. robustula* to *T. malayana* (Chasen, 1940).

Both *T. fulvida* and *T. malayana* were previously recorded from the Indian subcontinent (Bates & Harrison 1997). *Tylonycteris fulvida* occurs in southern and northeastern South Asia, southern China, and much of southeastern Asia (Bates et al. 2008a). In southern Asia, this species is widely distributed in and known from India (Andaman Islands, Karnataka, Kerala, Manipur, Meghalaya, Mizoram, Sikkim, Tripura, and West Bengal) (Molur et al. 2002; Das 2003) and Bangladesh (Khan 2001; Srinivasulu & Srinivasulu 2005). *Tylonycteris malayana* ranges from northeastern India through parts of southern China to much of mainland and insular southeastern Asia (Bates et al. 2008b). In southern Asia, this species is only recorded from Mizoram and Andaman Islands in India (Molur et al. 2002; Srinivasulu et al. 2018). Both these species are listed as Least

Table 1. Morphometric measurements of *Tylonycteris* sp. captured Gupteshore Cave at Kushma in Parbat, Nepal, compared with that of *T. fulvida* and *T. malayana*.

Parameters	Measurements (mm) (captured bat)	Bates & Harrison (1997)	
		T. fulvida (range)	*T. malayana* (range)
FA	26.9	26.1–29.0	26.6–28.1
HB	38.5	34.0–46.0	40.0–44.0
TL	25.8	26.0–33.0	26.0–31.0
HF	6.6	5.0–7.0	5.0–5.5
EL	9.3	9.0–10.0	8.5–10.5
TIB	11.6	-	-
3mt	26.4	23.8–27.0	25.8–26.4
1ph3mt	11.4	-	-
2ph3mt	14.6	-	-
4mt	26.6	23.8–26.9	25.4–26.0
1ph4mt	10.6	-	-
2ph4mt	7.1	-	-
5mt	26.1	23.2–26.0	24.8–25.6
1ph5mt	7.2	-	-
2ph5mt	3.5	-	-
BW (gm)	4	-	-

Image 1. Small Bamboo Bat *Tylonycteris fulvida* captured near Gupteshore Cave of Kushma, Parbat, Nepal: 1 - nostrils | 2 - shape of the head | 3 - ventral portion | 4 - lateral view | Blue circle - circular pads on thumbs | Red circle - pad on the sole of the hindfoot.

Concern in IUCN Red List (Bates et al. 2008a,b).

The study was conducted near the Gupeteshore Cave of Kushma (headquarters of Parbat District) during the field expedition of "Bats survey and conservation outreach programs along Kaligandaki Canyon of Nepal" funded by the Rufford Foundation (UK) in 2017. The cave is situated in steep slope pasture land with a small grove of trees forming a forest-like patch just above the cave structure, where trapping was conducted. The trapping area is dominated by *Dalbergia sissoo* and clusters of *Bambusa* sp.

Two mist nets (height 2.6m, lengths 4m & 6m, 38mm mesh) were deployed to capture the bats 30cm above the ground. Mist nets were left open from 18.00h to 21.00h and continuously checked at 10-minute intervals to reduce entanglement of the trapped bats. External morphometric measurements of the trapped bats were taken using vernier callipers (0.01mm accuracy). The measurements taken include head and body length (HB), forearm length (FA), ear length (EL), tail length (TL), hind foot length (HF), tibia length (TIB), 3rd metacarpal and phalanges length (3mt, 1ph3mt, 2ph3mt), 4th metacarpal and phalanges length (4mt, 1ph4mt, 2ph4mt), and 5th metacarpal and phalanges length (5mt, 1ph5mt, 2ph5mt). Body fur and other special features were noted. Body weight (BW) was measured using a

Pesola spring balance (1gm accuracy).

A single male specimen of *Tylonycteris* sp. was caught in the mist net located at 28.226^{0}N & 83.674^{0}E at an elevation of 868m on 27 April 2018 at 19.30h (two hours after sunset). The morphometric measurements are given in Table 1. The recorded location of *Tylonycteris* sp. is given in Fig. 1. The bat was released after images were taken. It was identified by referring to Bates & Harrison (1997) and consultation with experts in the field.

We identified the bat on the basis of its morphological characteristics: 1) shape of head, 2) circular pads on the base of thumb, 3) pad on the sole of the hindfoot, 4) lengths of 3rd, 4th, and 5th metacarpal, and 5) pelage colouration. *Tylonycteris* is a minute bat. Its head was characteristically flattened with the nostrils projecting forward and slightly downwards (Image 1). The fleshy pads at the base of the thumb and on the sole of the hindfoot were the most striking features of *Tylonycteris* (Image 1). The wings were short with the 3rd, 4th, and 5th metacarpals about equal in length (Table 1). The dorsal pelage was thick, short, and golden-brown, except for the muzzle which was darker, while the ventral pelage was not so dense and was paler (Image 1).

The wide distribution of *T. fulvida* along southern Asia, recorded at the closest location from Nepal, i.e., in India at Sikkim and Darjeeling of West Bengal (near the border of Nepal and India), body size, and distinguishing pelage colouration strongly suggest the captured bat to be *T. fulvida* rather than *T. malayana*, as the latter has no further record from southern Asia except from Mizoram (at the border of India and Myanmar) and the Andaman Islands in India (Molur et al. 2002; Srinivasulu et al. 2018). Additionally, the pelage colouration in *T. malayana* is uniformly grey-brown dorsally (as opposed to that of the captured bat) and slightly paler ventrally (Bates & Harrison 1997; Srinivasulu et al. 2018). With this note, we confirm the presence of *T. fulvida* in Nepal, highlighting the first record for the country.

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Is canine distemper virus (CDV) a lurking threat to large carnivores? A case study from Ranthambhore landscape in Rajasthan, India

Nadisha Sidhu [1], Jimmy Borah [2], Sunny Shah [3], Nidhi Rajput [4] & Kajal Kumar Jadav [5]

[1,2] WWF-India, Pirojsha Godrej Building, 172-B, Lodhi Estate, New Delhi 110003, India.
[2] Current affiliation: Panthera, 8 West 40 St. F. 18 NY 10018, USA.
[3] WWF-India, Western India Tiger Landsacape, Plot #19, 20, Subhash Nagar, Sawai Madhopur, Rajasthan 322001, India.
[4,5] School of Wildlife Forensic and Health, Nanaji Deshmukh Veterinary Science University, Jabalpur, Madhya Pradesh 482001, India.
[1] nadisha.sidhu@gmail.com, [2] jimmyborah@gmail.com (corresponding author), [3] envirosunn@gmail.com, [4] nidhi3rajput@gmail.com, [5] kaju_364@rediffmail.com

Abstract: Canine distemper virus (CDV) was reported in wild tigers from Russia and recently from India. Very few studies, however, have been carried out to gain an insight into the prevalence of the disease in India, particularly in the wild. CDV is the etiological agent of one of the most infectious diseases of domestic dogs. With the aim of exploring the threat CDV poses for tigers, a preliminary assessment was carried out to determine its prevalence from villages near Ranthambhore National Park in Rajasthan, India. Free-roaming dog populations within a 4-km-radius of the park's periphery were tested for antibodies against CDV. The seroprevalence of CDV antibodies in the sampled dogs was 86% (95% CI 78–91 %), indicating the probability of the dogs acting as a reservoir and having been exposed to CDV in the past. The seroprevalence of CAV antibodies was 44.23% (95% CI 35–54 %) and CPV antibodies was 95.19% (95% CI 91–99 %). This could threaten the tiger populations in the park, considering the close proximity of dogs to tigers. It is, therefore, crucial to assess disease threats at the domestic-wildlife interface and to establish management strategies for more effective conservation practices in the landscape.

Keywords: Disease dynamics, free-roaming dogs, Tiger, wildlife disease management.

The global Tiger *Panthera tigris* population faces threats due to various anthropogenic factors (Karanth & Chellam 2009; Walston et al. 2010; Jhala et al. 2015; Robinson et al. 2015). The populations also face new pressures associated with stochastic processes such as inbreeding depression and disease agents that have the potential to drive small, isolated populations to extinction (Timm et al. 2009; Kenney et al. 2014). In recent times, canine distemper virus (CDV) disease has emerged as one of the most highly contagious diseases with a fatality rate second only to rabies in canids (Nagao et al. 2012). The first major outbreak of CDV disease in large carnivores was reported in 1993 in the Serengeti, Tanzania, which reduced the lion population by 30% (Roelke-Parker et al. 1996; Nagao et al. 2012). In recent years, CDV has been recognized as a cause of death in Amur Tigers *Panthera tigris altaica* with the first diagnosed fatality from CDV in 2003 (Seimon et al. 2013). Following this, from 2004 to 2010, more CDV

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deaths in Amur Tigers were observed causing a significant decline in tiger numbers at Sikhote Alin (Gilbert et al. 2015). Recent reports have also confirmed cases of CDV in wild tigers in India (Guardian 2014). Studies in India looked at potential mitigation to prevent a spillover of diseases from dogs to wildlife (Belsare & Gompper 2013, 2015; Belsare et al. 2014). CDV spillover in endangered carnivore species is a serious conservation concern. Here we assess CDV antibody prevalence in free-roaming dog populations around a protected area in western India.

Methods

The study was conducted from July to August 2015 in the villages located in the peripheral area of the Ranthambhore National Park (RNP) located between 26.0173^{0}N and 76.5026^{0}E in Rajasthan, India. Villages located within a 4-km-radius of RNP were selected for sampling dogs. Free-roaming dogs found within these villages are most commonly known to wander into the park.

Dogs were caught with the help of villagers from the villages that fed and looked after them, and blood was collected via the cephalic vein using a hand-held syringe. Three to four dogs were sampled per village across 31 villages (Fig. 1). Blood samples were stored in EDTA vials at temperatures of 2–5 ^{0}C. A total of 121 samples was collected of which 17 samples were damaged during the collection and/or during transportation. Plasma was extracted from the remaining 104 samples and stored in a deep freezer maintained at -20^{0}C, at the School of Wildlife Forensic and Health, Nanaji Deshmukh Veterinary Science University, Jabalpur. The stored samples were analyzed for IgG antibodies against CDV using the DOT-enzyme linked immune sorbent assay (ELISA) test (Biogal's Immunocomb Canine Vaccicheck Antibody Test Kit; Biogal Galed Labs. Acs Ltd, Israel). A calibrated colour comb scale provided with the ELISA test kit was used to score the titer as high, moderate, or low. A high titer of IgG antibodies against CDV (>1:32 V.N. value) indicated a strong response to the antigen. The test kit is also designed to perform the titer test for two other pathogens—Canine Adenovirus (CAV) and Canine Parvovirus (CPV). Therefore, using the above-mentioned calibrated colour comb scale, a titer for antibodies against CAV and CPV was determined as well. A ≥1:16 V.N. value indicated a high antibody titer against CAV and similarly a ≥1.80 H.I. value indicated a high antibody titer against CPV.

Results

The seroprevalence of CDV antibodies in the sampled dogs was found to be 86% (95% CI 78–91 %). Only 14% of the samples showed negative results. None of the dogs tested had ever been vaccinated against CDV (pers. comm. district administration, 2015), suggesting that the dogs had prior natural exposure and recovery from CDV infection. The fact that a high percentage of dogs had been exposed to CDV could mean that they could potentially be a reservoir of the virus and that the dogs in these areas

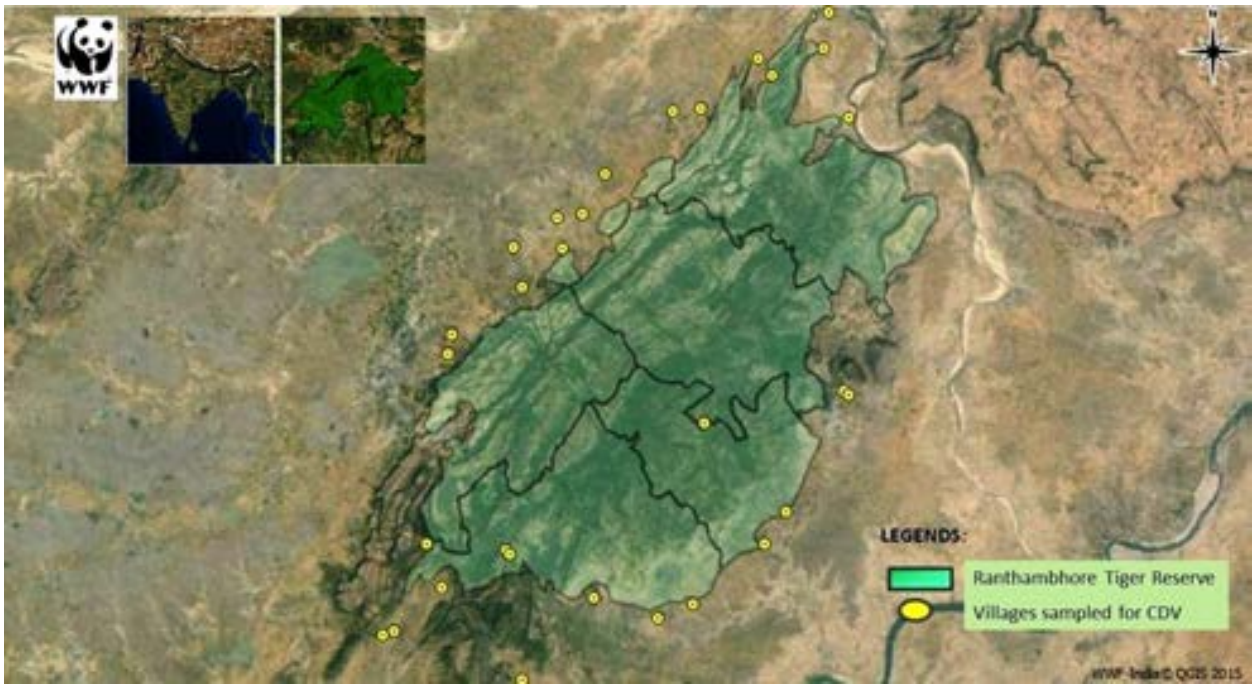

Figure 1. Villages sampled around Ranthambhore Tiger Reserve in Rajasthan, India.

were exposed to the virus through another infected animal or host. The seroprevalence of CAV antibodies in the sampled dogs was found to be 44.23% (95% CI 35–54 %). 46.15% of the samples tested negative for CAV. The seroprevalence of CPV antibodies in the sampled dogs was found to be 95.19% (95% CI 91–99 %). Only 2.88% of the samples tested negative for CPV.

Discussion

Our study reveals a moderate to high risk of exposure to CDV for the Tigers as well as the Leopards in RNP. With a population density of 6.4 Tigers per 100km^2 (Jhala et al. 2015), the transmission of the disease pathogen, in case of an outbreak, could be fairly rapid. A study of CDV infection in the local dog population surrounding the Serengeti in Tanzania has shown a spillover of CDV from the stray dog population to the lion population (Viana et al. 2015). Abundant free-roaming dog populations help expedite a higher contact rate between the stray dogs, livestock, and the wildlife population (Acosta-Jamett et al. 2015), which increases the risk of disease transmission and spread. The city of Sawai Madhopur, wherein RNP is situated, and the villages in the fringe of Ranthambhore is home to about 4,500 stray/feral dogs (Source: District Administration, Sawai Madhopur). Yoak et al. (2013) have also confirmed the presence of CDV in the stray dogs found in Sawai Madhopur. CDV antibodies have also been noted in exposed Wild Boar and deer species (Gilbert et al. 2015). CDV has been evaluated as a possible cause of disease and extinction risk in different species even outside of the order Carnivora and has also been demonstrated with serological evidence in a wide range of families and orders (Gutierrez & Saenz 2016). Further studies, however, will be required to determine and interpret this risk fully. Coexistence of susceptible and infected hosts could cause the back and forth transmission of the virus between multiple hosts, aiding the disease-causing pathogen to persist within a population or multiple species populations. This increases the threat for an endangered population of susceptible hosts such as the Tiger, particularly when the pathogen has the potential to increase the probability of extinction in the species (Gilbert et al. 2014).

It is, therefore, important to develop a disease surveillance strategy early on so as to deal with a probable CDV outbreak. Such a step requires an understanding of disease dynamics through further research. It would prove useful to obtain blood samples of live Tigers to test for the presence of CDV antibodies. For Tiger deaths reported within the park, it may be important to diagnose the presence or absence of CDV.

In an ideal situation, it would be preferable to maintain a smaller village dog population potentially for lower contact rates between dogs and wildlife and, therefore, fewer spillover events. Animal birth control (ABC) programs implemented in and around areas of conservation concern, in combination with restrictions to the movements of dogs in habitats occupied by species of conservation concern, might be useful in decreasing spillover events (Belsare & Gompper 2015).

Vaccination of local dog populations alone would probably be ineffective as a disease control strategy. Most adult dogs in such an environment are already immune to enzootic pathogens like CDV due to early natural exposure. As such, pup vaccination, rather than adult dog vaccination, should be evaluated as a potential disease control intervention (Belsare & Gompper 2015).

It is also suggested that disease control programs should have a strong component of public outreach (Belsare & Gompper 2015) and better awareness campaigns in such conservation concern areas. The National Tiger Conservation Authority, Government of India, has already issued a guideline for taking necessary preventive measures in and around protected areas (NTCA 2014). From a research perspective, a further epidemiological study should be undertaken to better understand the dynamics of CDV in natural ecosystems.

RNP, being home to 39 adult tigers, is an important source population for the species in the western part of India (Bhardwaj 2013; Jhala et al. 2015). Tigers from Ranthambhore have been translocated to places like Sariska and Mukundra, where the tiger population were locally extirpated. Therefore, it is imperative that such source populations are free from diseases like CDV, the outbreak of which in the region could cause a loss in the numbers of breeding females, affecting fecundity and thus causing an overall decline in species population. Therefore, such a source population needs to be managed with great efficiency in terms of disease management.

As human encroachment increasingly restricts the range of wild carnivores, the interaction between domestic animals and wildlife continues to rise. In such cases, urban-domestic species play a central role in the transmission of pathogens. RNP is situated in a high human population density area with over 300 villages located in a 5km-radius of the park (DeFries et al. 2010). There have been reports of Leopards killing stray dogs in the villages (Appel et al. 1994) which could possibly lead to the species contracting CDV from infected dog populations. Since Tigers and Leopards have prey resource overlap along with overlapping territories, CDV infection in Leopards increases the risk for disease contraction in the Tiger population.

Conclusion

The threat posed by multi-host diseases like CDV should be considered wherever Tigers coexist and interact with other carnivore species, as well in areas where villages are present adjacent to tiger reserves. While it is important to ensure that there is no spillover of CDV from the local dog population to Tigers and other wildlife, it is also imperative to maintain a stable population of such dogs through various means described earlier, so as to eliminate the risks of potential occurrence and transmission of diseases to the wild. The anthropogenic pressures in the form of poaching, retaliatory killings, and dog-transmitted diseases are a reflection of anthropogenic edge effects that occur in fragmented habitats (Gilbert et al. 2014). The most viable management strategy, therefore, would be to maintain Tigers in large and inter-connected populations that are able to withstand CDV and buffer the effects, should any outbreak occur. Our findings thus have important implications, highlighting a need to assess the reservoir dynamics of CDV to better assess the conservation threats to Tiger populations in the wild.

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Extended distribution of the vulnerable Cooper's Stone Flower *Corallodiscus cooperi* (Gesneriaceae) in India

Vikas Kumar [1], Samiran Panday [2], Sudhansu Sekhar Dash [3], Bipin Kumar Sinha [4] & Paramjit Singh [5]

[1,2] Central National Herbarium, Botanical Survey of India, Howrah, West Bengal 711103, India.
[3,4,5] Botanical Survey of India, CGO Complex, Sector 1, Salt Lake, Kolkata, West Bengal 700064, India.
[1] vmadhukar7@gmail.com, [2] samicnh@gmail.com,
[3] ssdash2002@yahoo.co.in (corresponding author),
[4] drbks2004@gmail.com, [5] pchanna@gmail.com

C.B. Clarke (1883) first established the genus *Didissandra* under the tribe Cyrtandreae. While describing the genus, he mentioned seven species under four sections, of which six belonged to the Malayan region and one (i.e., *D. lanuginosa*) to the Himalayan region (Shimla, Kumaun, Garhwal, Sikkim, and Khasia Hills in India, Bhutan, and China). Batalin (1892) established the genus *Corallodiscus* based on a specimen *C. conchaefolius* collected from China. Craib (1919a,b), while dealing with *Didissandra* and its allied genera in the context of India and China, recorded 16 species under the genus. According to Burtt (1947), however, the species mentioned under *Didissandra* by Craib (1919b) shows affinity with *Corallodiscus,* and hence he transferred all of Craib's species to *Corallodiscus*. Currently, most of the species have been synonymized (Wang et al. 1990, 1998; Gao et al. 2012) and the genus is characterized by six species, namely *C. bhutanicus* (Craib) B.L. Burtt, *C. cooperi* (Craib) B.L. Burtt, *C. conchifolius* Batalin, *C. grandis* (Craib) B.L. Burtt, *C. kingianus* (Craib) B.L. Burtt, and *C. lanuginosus* (Wall. ex DC.) B.L. Burtt (The Plant List 2013). According to Mabberley (2018), this genus comprises 3–5 species, distributed from the Himalaya to northwestern China and southeastern Asia. So far, only *C. kingianus* and *C. lanuginosus* have been reported from India.

During our floristic and ecological study in Tawang District of Arunachal Pradesh under the project titled 'Biodiversity Assessment through Long-term Monitoring Plots in Indian Himalayan Landscape', we collected an interesting species belonging to *Corallodiscus*. Upon critical analysis and scrutiny of authentic literature (Ridley 1905; Craib 1919a,b; Wang et al. 1998; Hilliard 2001; Kamble et al. 2006; Giri et al. 2008; Rout et al. 2008; Möller et al. 2017) and study of herbarium material form from Botanical Survey of India, Arunachal Pradesh Regional Centre, Itanagar (ARUN), Botanical Survey of India, Eastern Regional Centre, Shillong (ASSAM), Central National Herbarium, Howrah (CAL), and Royal Botanic Garden, Edinburgh (E), the identity of the species was confirmed as *Corallodiscus cooperi* (Craib) B.L. Burtt., hitherto not reported from India. According to IUCN (2017) criteria, the species is listed under the Vulnerable category and was previously only reported from Bhutan. Therefore, the collection of this species from Zemithang establishes its extended distribution and occurrence in India. A detailed description of this newly recorded species along with field images, locality map (Fig. 1), and notes are provided herewith to facilitate its easy

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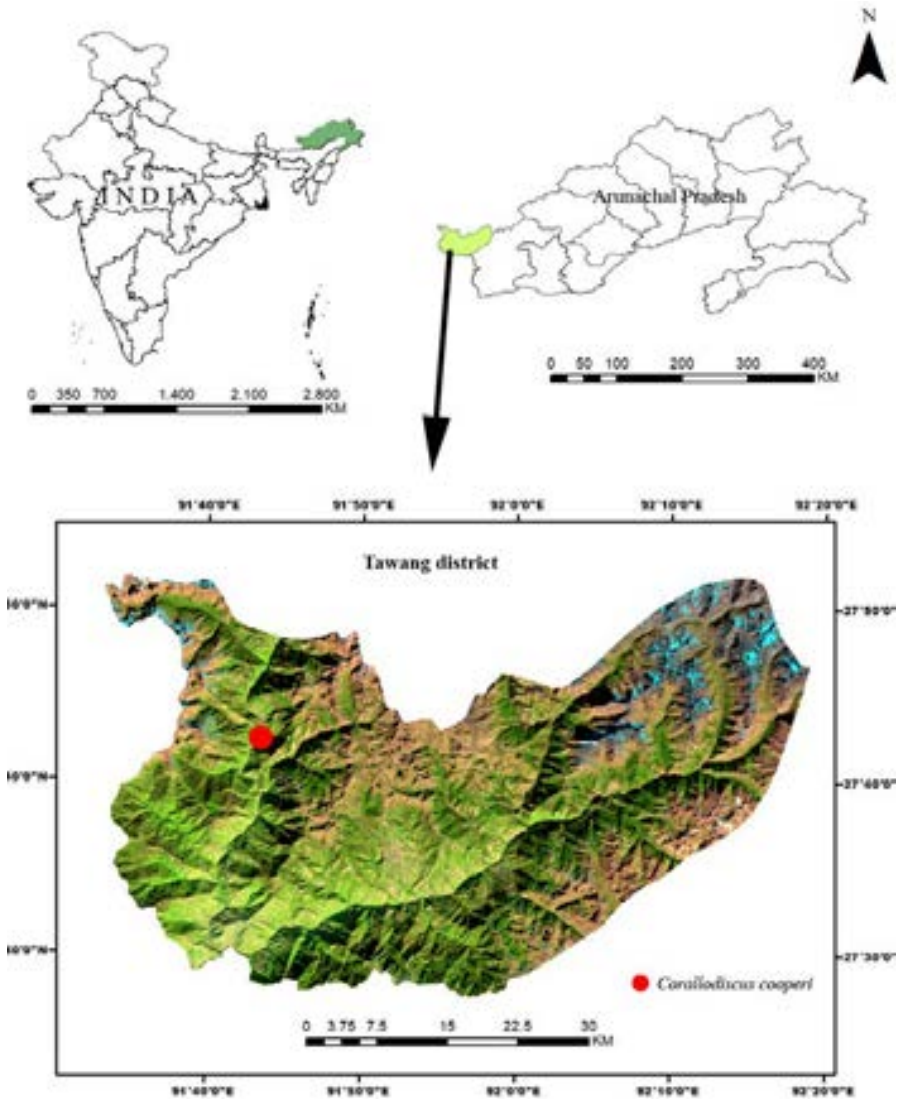

Figure 1. ***Corallodiscus cooperi*** **in Zemithang in Tawang District, Arunachal Pradesh, India (Landsat-8; false colour composite using 6,5,4 bands).**

identification.

Material and Methods

Flowering specimens of the species were collected from Zemithang Valley in August 2017. The floral parts were dissected and observed under the light microscope (Olympus SZ61) for detailed macro- and micromorphology. Images were taken in the field with a Sony DSC-HX60V camera. Colour photoplates were made using Adobe Photoshop CS3 and the locality map using Arc Map (ver. 10.1).

Corallodiscus cooperi **(Craib) B.L. Burtt.**

in Gard. Chron. III, 122: 212. 1947; Hilliards in A.J.C. Grierson & D.G. Long (Eds.) Flora of Bhutan, 2(3): 1322. 2001. Type: Bhutan, Dotena Timphu, 8000ft, *Cooper* 2508/a (E-image!) (Image 1).

Didissandra cooperi Craib in Notes Roy. Bot. Gard. Edinburgh 11: 241–242. 1919.

Small, acaulescent, rosettiform, stoloniferous, lithophytic herb. Rhizome usually grows above ground. Leaves radical, rosette, erect or suberect, smooth; petiole 1.2–1.5 cm long, woolly; lamina narrowly elliptic to oblong or subspathulate, (1.5) 5–8 cm × 3.0–3.5 cm, narrowly cuneate at base, gradually tapering to an elongated petiole, entire at margin, acute to obtuse at apex; lateral veins 2–3 pairs, thick, faint on upper surface, prominent on lower surface; adaxially glabrous, glaucous, slightly woolly along veins at abaxial surface. Flower axillary, solitary, 1.6–2.0 cm long, purplish-white; pedicel, 6.5–8.0 cm long, cylindrical, usually drooping at apex in bud, purplish-brown, woolly at base, glabrescent

Image 1. A, B & C - Habit of *Corallodiscus cooperi* | D - Adaxial view of leaf | E - Abaxial view of leaf | F & G - Flower | H - Sepals | I - Corolla | J - Corolla showing stamens | K - Stamens. © Vikas Kumar.

Key to the species of *Corallodiscus* in India

1a. Flowers solitary; peduncles, pedicels and calyx persistently woolly ..... *C. kingianus*
1b. Flowers 1–many; peduncles, pedicels and calyx glabrous or glabrescent 2
2a. Plant stoloniferous; leaf glabrous adaxially, 2–3 pairs of lateral veins, faint on adaxial surface; margin entire; cyme 1-flowered ..... *C. cooperi*
2b. Plant not stoloniferous; leaf usually hairy adaxially, 3–5 pairs of lateral veins, prominent on adaxial surface; margin entire or subcrenate; cymes 1–many flowered ..... *C. lanuginosus*

towards apex. Calyx bell-shaped, segments equal in size, connate at base, sepals 5, imbricate, ovate, 2–3 mm × 1.0–1.5 mm, apex acute and minutely recurved, brown, margin entire. Corolla tubular, ca. 7.5mm long, bilipped, purplish; inside with two rows of yellow spots, outer surface glabrous, inner surface woolly; upper lip 2-lobed, ca. 4mm long, suborbicular, obtuse at apex; lower lip 3-lobed, ca. 5mm × 4mm, obovate to sub-orbicular. Stamens 4, didynamous, epipetalous, longer stamens 8–9 mm long, shorter ones 5–6 mm long; anthers dorsifixed, each pair of anther connate at apex, white; staminode 1. Carpels ca. 5mm × 1mm, glabrous; ovary ca. 2mm long, unilocular; style ca. 3mm long, slender; stigma bilobed.

Flowering: August–September.

Habitat and ecology: Grows on slopes, in rocky crevices, and on moss-covered boulders at an altitude of ca. 1,900–2,000 m. Three populations with ca. 35 mature individuals were observed along a 1km-long trail during our field visit of which, two specimens (same field no.) were collected for herbarium. The associated species were *Lycopodium japonicum* Thunb., *Selaginela monospora* Spring., *Cyanotis vaga* Schult. & Schult.f., and *Nephrolepis cordifolia* (L.) C. Presl.

Distribution: India (Arunachal Pradesh) and Bhutan.

Status: Vulnerable (IUCN 2017).

Specimen examined: 87268 (CAL!), 14.viii.2017, Arunachal Pradesh, Tawang District, Zemithang Valley, 27.706^{0}N & 91.724^{0}E, 2,075m, coll. V. Kumar & S. Panday.

Notes: Though *Corallodiscus cooperi* is allied to *C. lanuginosus*, it differs from it in having a stoloniferous habit, smooth leaf blades, glabrous and glaucous upper leaf surface, faint and inconspicuous veins, and inflorescence with solitary flower. It also shows similarities with *C. bhutanicus* and *C. conchifolius* in habit, but differs from *C. bhutanicus* in having narrowly elliptic-oblong to subspatulate leaves and smaller size of calyx and from *C. conchifolius* by the presence of leaves having an entire margin, sparsely woolly hairs restricted to the veins on abaxial surface, and small size of calyx (ca. 2mm long).

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Extended distribution record of two bellflower species of *Codonopsis* (Campanulaceae) from the Indian state of Arunachal Pradesh

Khilendra Singh Kanwal [1], Umeshkumar Lalchand Tiwari [2], Lod Yama [3] & Mahendra Singh Lodhi [4]

[1,3,4] G.B. Pant National Institute of Himalayan Environment and Sustainable Development, North East Regional Centre, Itanagar, Arunachal Pradesh 791111, India.
[2] Botanical Survey of India, Arunachal Pradesh Regional Centre, Itanagar, Arunachal Pradesh 791111, India.
[1] kskanwal03@gmail.com, [2] tigerumesh11@gmail.com (corresponding author), [3] lod1437@gmail.com, [4] mahen29.mail@gmail.com

The genus *Codonopsis* Wall. (Campanulaceae) consists of about 42 species, widely distributed in tropical and temperate to alpine regions of Asia and Europe (Haridasan & Mukherjee 1996; Hong 2015). In India, the genus is mainly distributed in temperate, sub-alpine, and alpine regions of the Himalaya. The name *Codonopsis* was given by Wallich (1824). Derived from the Greek word 'kodon/ codon' meaning bell and the Latin suffix '-opsis' used to indicate resemblance, the name refers to the shape of its flower, which is similar to that of a bell. Among the *Codonopsis* species, *C. pilosula* (Franch.) Nannf. and *C. lanceolata* (Sieb. et Zucc.) Benth. & Hook. f. ex Trautv. are more popular than the others, especially due to their phytochemical activities (He et al. 2015). According to Kala (2010), *C. clematidea* (Schrenk) Cl., *C. ovata* Benth., and *C. rotundifolia* Benth of the western Himalaya are used in indigenous medicine by 'amchis' for curing skin diseases. "Sowa-Rigpa" commonly known as amchi system of medicine is one of the oldest living and well documented medical tradition of the world. It has been popularly practice in Tibet, Magnolia, Bhutan, some parts of China, Nepal, Himalayan regions of India and few parts of former Soviet Union.

A survey was carried out in Tawang District of Arunachal Pradesh during 2016–2017 for the assessment of the floral diversity of high altitude areas. *Codonopsis foetens* and *C. thalictrifolia* were collected from Kyo Tso Wetlands (27.696^{0}N & 91.842^{0}E, 4,245m) and Nagula Tso Wetlands (27.654^{0}N & 91.863^{0}E, 4,070m), respectively. These two species of *Codonopsis* are very rare and endemic to the eastern Himalaya and have a limited distribution in Sikkim, Bhutan, and China. The Nagula Wetland complex area is rich in high altitude floral diversity and is little explored at present. The identification of the species was confirmed through consultation of type specimens and the protologue of the species. Further consultation of important literature (Clarke 1882; Haridasan & Mukherjee 1996; Chowdhery et al. 2008; Pal 2013; Tiwari 2015–2016; Dash & Singh 2017) and of herbarium at various institutions, such as the Botanical Survey of India, Itanagar (ARUN), the State Forest Research Institute (SFRI), Itanagar, and the Royal Botanic Gardens, Kew (K), United Kingdom, were done for the identification of the species and the gathering

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of information on their historical distribution. These sources revealed that the species were not reported earlier from Arunachal Pradesh and that, in India, these were known from Sikkim and Darjeeling District of West Bengal. Therefore, these species are presented here as new distribution records for the state of Arunachal Pradesh. The present communication provides detailed descriptions with type, ecology, and images of the collected plant species. The specimens are deposited in the herbarium of the G.B. Pant National Institute of Himalayan Environment and Sustainable Development in Itanagar and at BSI APRC Itanagar (ARUN) for future references.

Codonopsis foetens

J.D.Hooker & Thomson, J. Proc. Linn. Soc., Bot. 2: 16. 1858; C.B. Clarke in Hook.f., Fl. Brit. India 3: 433.1882 (Image 1).

Type: India, Sikkim, J.D.Hooker s.n. (K!) Ascending herbs, roots slender, 10–55 cm × 1–2 cm. Caudexes abundantly branched, and thus stems several to many from one caudex, caespitose. Main stem erect or ascending, 20–40 cm tall, villous; branches numerous, aggregated in the lower part, 1–10 cm tall, usually sterile. Leaves on main stems alternate, those on branches opposite or subopposite; broadly ovate to elliptic-ovate, caudate to cordate at base, 3–11 mm × 3–10 mm, densely white pilose on both surfaces; margin entire or subentire, apex obtuse; petiole 1–3 mm, pilose. Flowers solitary (rarely several), terminal on main stems and sometimes branches, ± pendent; pedicels 4.5–3.5 cm, terminal, glabrous or sparsely pilose. Hypanthia 3–4 mm × 7.5–9.0 mm, broadly subglobose, glabrous or sparsely pilose. Calyx tube adnate to ovary up to middle, semiglobose or hemispherical, glabrous or very sparsely white hispidulous, perigynous; lobes ovate, ovate-oblong, or ovate-lanceolate, 7–20 mm × 2–7 mm, rather densely hispidulous, entire, recurved at margin, apex acute or obtuse. Corolla epigynous, pale blue or pale purple with interior markings, globose-campanulate, 2.0–4.5 cm × 2.5–3 cm; lobes suborbicular, 8–12 mm, apex obtuse or acute, tube 15–20 mm long. Stamens glabrous; filaments slightly dilated at base, ca. 5mm; anthers 4–5 mm; anther 3–5 mm long. Ovary semi inferior; style ca. 9mm long. Capsule obconical at inferior part, conical at superior part, ca. 2.0cm × 1.5cm. Seeds brownish-yellow, ellipsoid or oblong, ca. 1mm, smooth.

Flowering and fruiting: July–October.

Habitat: Found in the alpine habitats of the Himalaya at an elevation of 3500–4500 m along grassy slopes, alpine scrub, crevices, forests, and meadows at forest margins on north-facing slopes.

Image 1. *Codonopsis foetens* Hook.f. & Thoms.: A - Habit | B - Leaves | C - Closeup of open flower. © K.S. Kanwal.

Distribution: India (Sikkim and Arunachal Pradesh), Bhutan, Nepal, and China (Xizang, Zizhique, and northwestern Yunnan).

Specimen examined: (ARUN!) 1020, 11.viii.2017, India, Arunachal Pradesh, Tawang District, 27.696^{0}N & 91.842^{0}E, above 4,000m, coll. Lod, Roona & K.S. Kanwal (Image 3).

Ecology and threats*:* This terrestrial plant grows on grassy slopes in alpine pastures near Kyo Tso Wetlands. The species is facing threats from grazing by domestic animals (mainly yak and sheep), firewood collection, unregulated tourism, solid waste generation, and development projects. Climate change may be a future threat for the species. Therefore, in situ and ex situ conservation measures are essentially required for the conservation of this species.

Codonopsis thalictrifolia

Wall. in Roxb., Fl. Ind. 2: 106. 1824; Hook.f. & Thoms. In J. Linn. Soc. 2:16 1858; C.B. Clarke in Hook.f., Fl. Brit. India 3: 432.1882. (Image 2)

Type: Nepal, Gosainthan, *Wallich cat. no. 1297* (K!)

Ascending herbs, 10–35 cm high; roots carrot-shaped, 15–20 cm × 0.5–1.0 cm. Stems robust, sparsely pilose or glabrous, profusely branched near base; branches sterile, slender, leafy, aggregated at base of

Image 2. ***Codonopsis thalictrifolia*** **Wall. in Roxb.: A - Habitat | B - Habit | C - Closeup of open flower. © K.S. Kanwal.**

main stems, 4–6 cm, villous. Leaves on main stems alternate, those on branches subopposite; petiole ca. 2mm, white hirsute; blade ovate or suborbicular, 2.0–5.5 mm × 2–6 mm, both surfaces villous, base cordate or truncate, margin sub-entire or crenate, apex obtuse or acute. Flowers solitary, terminal on main stems, slightly pendent. Hypanthis 1.5–2.0 mm × 6–8 mm, broadly obconic, scabrid-pilose. Calyx tube perigynous; adnate to ovary up to middle, hemispheric, 3–5 mm × 6–10 mm, glabrous or villous; lobes triangular or oblong, 5mm × 3mm, outside hairy, margin entire, apex acute or obtuse; sinus between lobes broad and obtuse. Corolla tubular-campanulate, 2.0–4.8 cm × 1.5–4.3 cm, shallowly lobed; lobes triangular, 2–4 mm × 7–9 mm, apex obtuse; tube pale blue, 18–23 mm long, glabrous or occasionally sparsely villous. Filaments slightly dilated at base, ca. 1cm; anthers ca. 3mm, villous at connective. Capsule hemispherical at base, conical toward apex, rostrate. Seeds numerous, brownish-yellow, ellipsoid, smooth.

Flowering and fruiting: July–October

Habitat: Found in the alpine habitats of the Himalaya at an elevation of 3300–4500 m along grassy slopes, alpine scrub, crevices, forests, and meadows at forest margins on north-facing slopes.

Distribution: India (Singalelah in West Bengal, Dzongri to Aloktong in Sikkim, and Arunachal Pradesh), Bhutan, Nepal, and China (Xizang and Zizhique).

Specimen examined: (ARUN!) 1019, 11.viii.2017, India, Arunachal Pradesh, Tawang District, three samples, 27.654^{0}N & 91.863^{0}E, 4,000m, coll. Lod, Roona & K.S. Kanwal (Image 4).

Ecology and threats*:* The species grows on the hilltop of an alpine pasture of Nagula Lake. Grazing, fuelwood collection, tourism activities, infrastructure establishment, and change of land use pattern were observed as some of the threats for the species in the area. The catchment area of the lake is used as a grazing site by the local villagers for their cattle, mainly yak

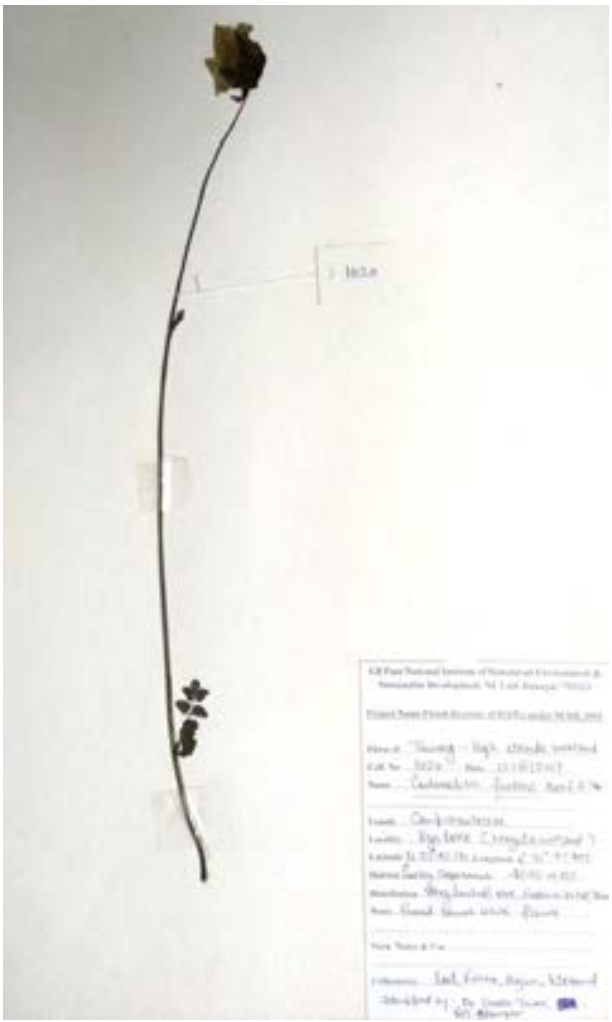

Image 3. Herbarium image of *Codonopsis foetens* [(ARUN!) 1020].

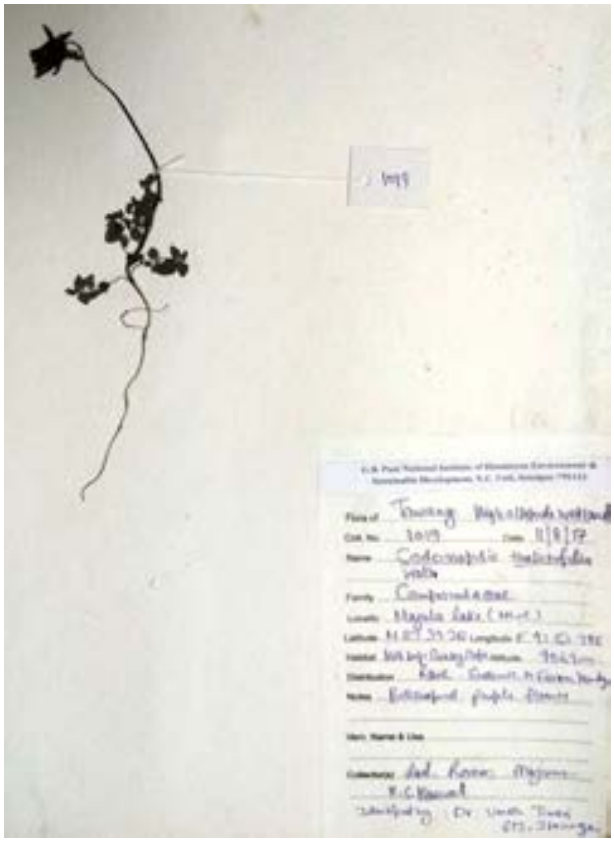

Image 4. Herbarium image of *Codonopsis thalictrifolia* [(ARUN!) 1019].

and sheep. The species may face a further threat from climate change in the near future. Hence, conservation and management measures are required for the conservation of this species.

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PLATINUM OPEN ACCESS

First record of the Blue-and-white Flycatcher *Cyanoptila cyanomelana* (Temminck, 1829) (Aves: Passeriformes: Muscicapidae) from Bhutan

Kado Rinchen [1], Kinley Kinley [2], Chhimi Dorji [3] & Dorji Wangmo [4]

[1] Jigme Singye Wangchuck National Park, Department of Forest and Park Services, Bhutan.
[2,3] Tsirang Forest Division, Department of Forest and Park Services, Bhutan.
[2] Landscape Ecology and Nature Conservation, University of Greifswald, Greifswald 17489, Germany.
[4] Damphu Lower secondary School, Ministry of Education, Bhutan.
[1] kado.rinchen@gmail.com (corresponding author), [2] kinley@moaf.gov.bt, [3] chhimidorji@moaf.gov.bt, [4] dorjiwangmo146@education.gov.bt

The Blue-and-white Flycatcher *Cyanoptila cyanomelana* is known to be a summer visitor to northeastern Asia, moving towards the south during winter to Taiwan, southeastern China, and southeastern Asia, through the Greater Sunda Islands to the Philippines (Clement & Taylor 2006). It is a recent addition to the South Asian avifaunal database. It is not listed in Ali & Ripley (1987), Rasmussen & Anderton (2005), or Grimmett et al. (2011).

According to Choudhury (2006) the bird has been observed on rare occasions in northeast India and was sighted once 16 years ago on 24 November 2002 in Upper Siang District, Arunachal Pradesh in India.

In the past, this species has been reported from several isolated localities in the Indian subcontinent; nine locations in India as reported by Choudhury (2006), Kawale (2013), Rajeshkumar et al. (2014), Barve & Kamath (2016), Bhoopathy & Indrajith (2016), Praveen et al. (2016), and one record in Sri Lanka (Vidanapathirana et al. 2014).

During patrolling duty in Jigme Singye Wangchuck National Park on 14 April 2018, a male Blue-and-white Flycatcher was observed and photographed at an elevation of 1,610m on abandoned land at Dimba Village (27.419^{0}N & 90.469^{0}E) under Tangsibji Block in Trongsa District. It was observed perching on a tree in a broadleaved forest with vegetation dominated by *Quercus grifithii*, along with other broadleaved species like *Lyonia* spp., *Rhus* spp., Dog wood, *Bahunia* spp., *Erythina* spp., and *Alnus* spp.. Several small clumps of bamboo were also observed in and around the bird observation area.

After referring to several online websites such as Birdlife International, ebird and circulation of the photographs amongst many birdwatchers through the social media facebook forum Birds of Bhutan, the bird was initially identified as a male Blue-and-white Flycatcher by Tim Inskipp and was later confirmed by Dr. Sherub, ornithologist at Ugyen Wangchuck Institute for Conservation and Educational Research Institute in Bhutan. It is the first record for the Himalayan kingdom of Bhutan. The new record adds the 729th bird species for Bhutan (Dr. Sherub pers. comm. April 2018). With this observation, the Blue-and-White Flycatcher is known to occur in three countries of the Indian subcontinent. Clement & Taylor (2006) described the Blue-and-White

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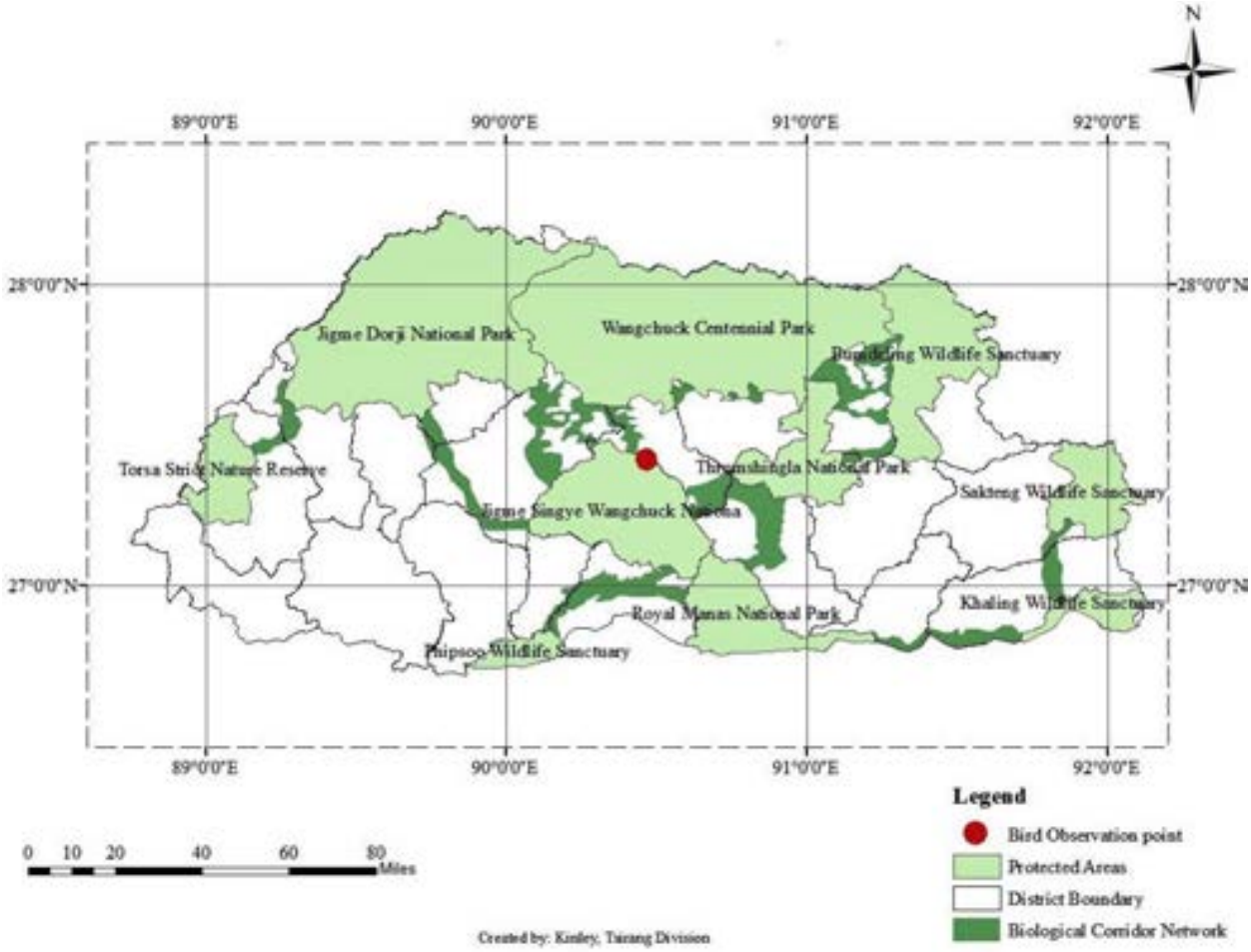

Figure 1. Observation point of the Blue-and-white Flycatcher in Bhutan.

Figure 2. Male Blue-and-white Flycatcher perched on a tree observed in Bhutan.

Flycatcher as a passage migrant through southern and southeastern China between early or mid-December to mid-February and returning to its breeding sites through Guangdong from mid to late March. This Bhutan record proves that the Blue-and-white Flycatcher can migrate as late as mid-April. Possibly, while on their return migration, a few birds might sojourn in various places in Bhutan or elsewhere in the subcontinent's mainland before reaching their breeding grounds. There could be other undetected incidences of migrant species' occurrence in the country and it would be useful if more observations were carried out during bird migration seasons to discover such instances. The development of a long-term bird monitoring protocol for Bhutan to ensure the survival of all residents and migratory birds is recommended.

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Butterflies collected using malaise traps as useful bycatches for ecology and conservation

Augusto Henrique Batista Rosa [1], Lucas Neves Perillo [2], Frederico Siqueira Neves [3], Danilo Bandini Ribeiro [4] & André Victor Lucci Freitas [5]

[1,2,3] Departamento de Biologia Geral, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil.
[4] Instituto de Biociências, Universidade Federal de Mato Grosso do Sul, Campo Grande, Brazil.
[5] Departamento de Biologia Animal and Museu de Zoologia, Instituto de Biologia, Universidade Estadual de Campinas, Campinas, São Paulo, Brazil.
[1] augustohbrosa@hotmail.com (corresponding author), [2] lucasnevesperillo@gmail.com, [3] fred.neves@gmail.com, [4] biodbr@gmail.com, [5] baku@unicamp.br

Sampling insects using flight interception traps (e.g., malaise traps) is very effective for taxonomic, population, and community studies (Matthews & Matthews 1971; Campbell & Hanula 2007; Perillo et al. 2017). This method is generally focused on the collection of flying insect groups such as Hymenoptera, Diptera, and Coleoptera (Gressitt & Gressitt 1962; Brown 2005; Souza et al. 2015); however, other insect groups too are frequently sampled as bycatches and their information can be certainly used for several purposes. From 2013 to 2016, a study on hymenopteran communities (bees and wasps of Aculeata) was carried out throughout the Espinhaço Mountain range (12 sample locations, 700–2,070 m) in the Brazilian states of Minas Gerais and Bahia. In total, 120 malaise traps were maintained in the field for 10 consecutive days during the rainy season from November to February. A total of 1,000 butterflies belonging to six families, namely, Pieridae (n=353), Nymphalidae (n=274), Hesperiidae (n=205), Lycaenidae (n=139), Riodinidae (n=17), and Papilionidae (n=12), were captured during the study period. As expected, because of the collecting method (many insects captured together in an ethanol-filled recipient), most butterflies became mangled and discoloured, making them hard to identify (Fig. 1; Schmidt 2016). Nevertheless, three interesting species were reported among in the collected material as they were either threatened, endemic, or undescribed (all from Minas Gerais State) (Fig. 1). These were: 1. *Strymon ohausi* (Spitz, 1933) (Lycaenidae; Image 1A (ZUEC-LEP 11044); 2. *Yphthimoides cipoensis* (Freitas, 2004) (Nymphalidae; Image 1B (ZUEC-LEP 11045) (both deposited at the Zoology Museum in Campinas University, Campinas, São Paulo, Brazil); and 3. an undescribed species of *Aricoris* (Riodinidae; Image 1C (LAK-479, LAK-481 and LAK-482; in process of description, not yet formally deposited in a collection)). The lycaenid *S. ohausi* is considered Endangered (EN) in the Brazilian Red List of threatened fauna; a single individual was collected in

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Competing interests: The authors declare no competing interests.

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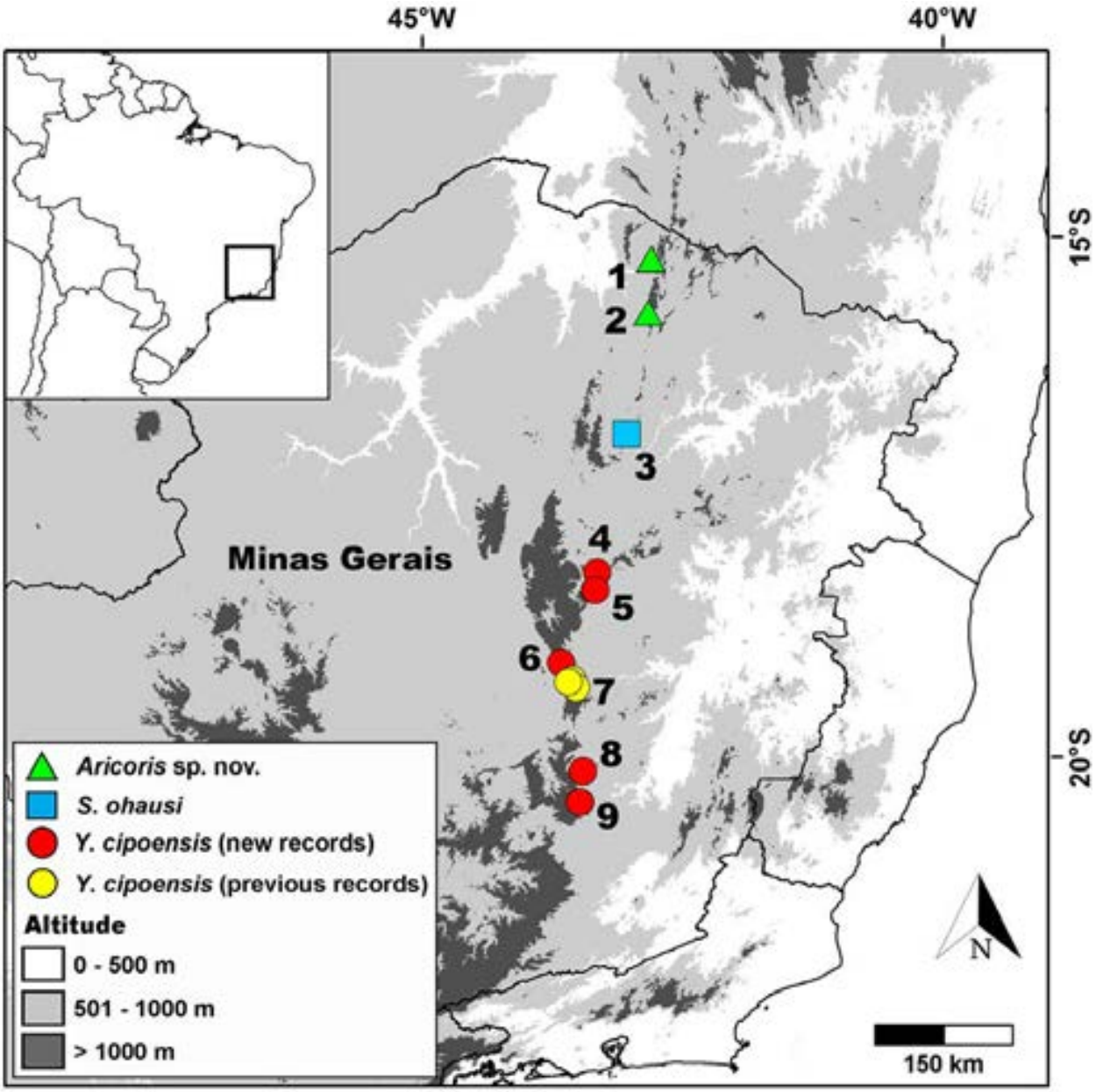

Figure 1. Collecting sites in Minas Gerais, Brazil : 1 - Serra Nova State Park, Porteirinha | 2 - Pico da Formosa, Santo Antônio do Retiro | 3 - Botumirim State Park, Botumirim | 4 - Rio Preto State Park, São Gonçalo do Rio Preto | 5 - Pico do Itambé State Park, Santo Antônio do Itambé | 6 - Pico do Breu, Santana do Riacho | 7 - Serra do Cipó (three nearby sites), Santana do Riacho | 8 - Serra do Caraça, Catas Altas | 9 - Itacolomi State Park, Mariana.

Botumirim State Park, Botumirim, representing a new occurrence record for the species. For the nymphalid *Y. cipoensis*, an endemic species previously known from three localities in the Serra do Espinhaço (Freitas 2004), seven individuals were collected in five localities, which are all new occurrence records for the species. An undescribed species of *Aricoris* (Riodinidae) (J.R. Lemes & L.A. Kaminski pers. comm. January, 2018), identified primarily by DNA sequencing, was collected in two localities and will add important geographic information for its description. The new records were important in expanding the distribution ranges of the former two species. For *S. ohausi*, the extent of occurrence (EOO) and occupancy area (AOO) increased from 423,600km^2 and 48km^2 to 472,500km^2 and 52km^2, respectively. For *Y. cipoensis*, the increase in both EOO and AOO were much larger, from 22km^2 and 12km^2 to 6,800km^2 and 36km^2, respectively. This means that the assessment for

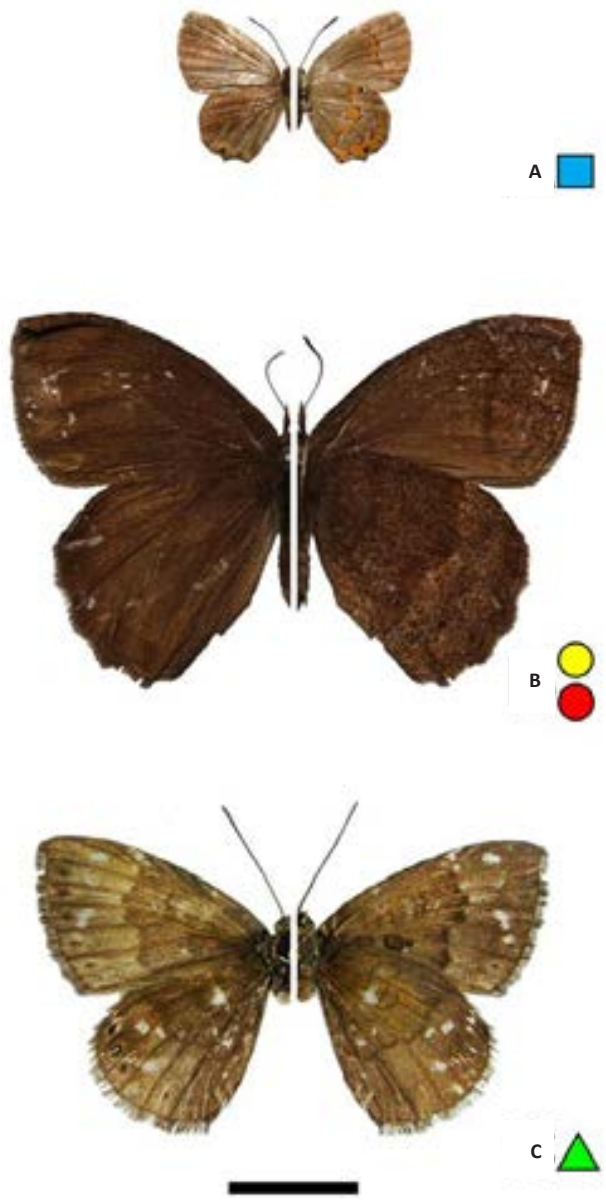

Image 1. Butterflies collected with malaise traps: A - *Strymon ohausi* | B - *Aricoris* sp. | C - *Yphthimoides cipoensis* (left - dorsal view, right - ventral view; bar = 1cm). © Augusto H.B. Rosa and André V.L. Freitas.

Y. cipoensis under criterion B (geographic distribution) (IUCN 2012) changes from Critically Endangered (CR B1) to Endangered (EN B2), a more realistic conservation status. These new records highlight the importance of storing and making available all collected material in large biological inventories, even when these are not the focal taxa of the study. In the present case, although most butterflies in malaise traps got tattered and were difficult to identify, their data was important for providing relevant information for taxonomic, genetic, and conservation studies.

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Notes on the hairstreak butterflies *Euaspa* Moore, 1884 (Lepidoptera: Lycaenidae) with new distribution records to the Indian eastern Himalaya

Gaurab Nandi Das [1], Subrata Gayen [2], Motoki Saito [3] & Kailash Chandra [4]

[1,2,4] Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata, West Bengal 700053, India.
[3] The Research Institute of Evolutionary Biology (Insect Study Division), 2-4-28, Kami-youga, Setagaya-ku, Tokyo 158-0098, Japan.
[1] gaurab68nandidas@gmail.com (corresponding author), [2] gayensubrata89@gmail.com, [3] m19s29sm@za2.so-net.ne.jp, [4] kailash611@rediffmail.com

The genus *Euaspa* Moore, 1884 (Lycaenidae: Theclinae: Theclini) was described from a single male specimen of *Myrina milionia* Hewitson, 1869 (currently *Euaspa milionia*) collected by Hewitson from Shimla in Himachal Pradesh, India (Moore 1884). The description was imprecisely elaborated, based on a few superficial morphological characters (de Nicéville 1890). Later, de Nicéville (1890) articulated the generic description in detail based on wing venation and wing maculation, after examining specimens from Kulu (Himachal Pradesh) and Mussoorie (Uttarakhand) of India. Subsequently, Shirôzu & Yamamoto (1956) did phylogeny and generic revision of the tribe Theclini, based on the external male and female genitalia of the type specimens of *E. milionia* Hewitson, 1869. Koiwaya (2002) described six new species of *Euaspa* from different countries of southeastern Asia such as Myanmar, Laos, and Vietnam, of which two were described from India, namely: *E. miyashitai* Koiwaya, 2002 from Darjeeling in West Bengal and *E. mikamii* Koiwaya, 2002 from Arunachal Pradesh. Sidhu (2007) described the male and female genitalia of *E. milionia* from Uttarakhand and Himachal Pradesh. Koiwaya (2007) recognized 12 species under this genus and more recently described *E. uedai* from China (Koiwaya 2014). Most recently, Huang (2016) described *E. zhengi* from China, aggregating 14 species worldwide.

In India, four species of *Euaspa* are reported till date, namely: *E. milionia milionia* (Hewitson, [1869]), *E. pavo* (de Nicéville, 1887), *E. mikamii* Koiwaya, 2002, and *E. miyashitai* Koiwaya, 2002 (Varshney & Smetacek 2015). The global distribution of all species of *Euaspa* (Koiwaya 2007) revealed that *E. milionia* is the most widely distributed species in the region, from the northwestern Himalaya to Taiwan (Fig. 1), although the majority of the species are known from a few locality records alone. This paper contributes to the global distribution range

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of *E. motokii* Koiwaya, 2002 with the first record from India and a new locality record for *E. mikamii* Koiwaya, 2002 from the Dihang-Dibang Biosphere Reserve (DDBR) in Arunachal Pradesh, India.

***Euaspa motokii* Koiwaya, 2002**

E. motokii Koiwaya, 2002, *Gekkan-Mushi*, 377: 2–8

Type locality: Naungmon in Kachin State, Myanmar.

Distribution: Myanmar and northeastern India.

Diagnostic: *Euaspa motokii* can be identified from all other congeners by the following characters: on subterminal area of underside of forewing in space 1b to 2 having a less prominent blackish mark, which is being prominent in similar species *E. forsteri* (Esaki & Shirôzu, 1943); two discal white zig-zag lines on underside of hindwing (Image 2iic); two subbasal white markings on the underside of hindwing, the one oval shape in cell and the other semi-circular in space 7 (Image 2iid).

Current record: On 07 June 2017, a single individual was photographed (Image 2ii) at around 11.00h near Anini (28.784^{0}N & 95.876^{0}E; 1369m) in DDBR, Arunachal Pradesh. The individual was sighted in a subtropical broadleaved evergreen forest, where it was active on a leaf of an oak sapling (*Castanopsis* sp.) at a height of about 2m from the ground level. *Castanopsis* is known as the foodplant of some *Euaspa* species including *E. motokii* (Koiwaya 2007).

Remarks: *Euaspa motokii* was described by Koiwaya (2002) on the basis of a male specimen collected by one of the authors in this paper (Motoki Saito) in 2000 from the Kachin State of Myanmar at 1200–1600 m. Subsequently, the eggs were collected by his colleague from *Castanopsis* spp. and the early stages were documented. Two specimens from these rearing eggs were illustrated in Koiwaya (2007). Known specimens, however, are still only a few, including the holotype specimen collected in the wild; this species was thought to be endemic in Myanmar. The present record extends the distribution range of the species from Myanmar to the eastern Himalaya of India.

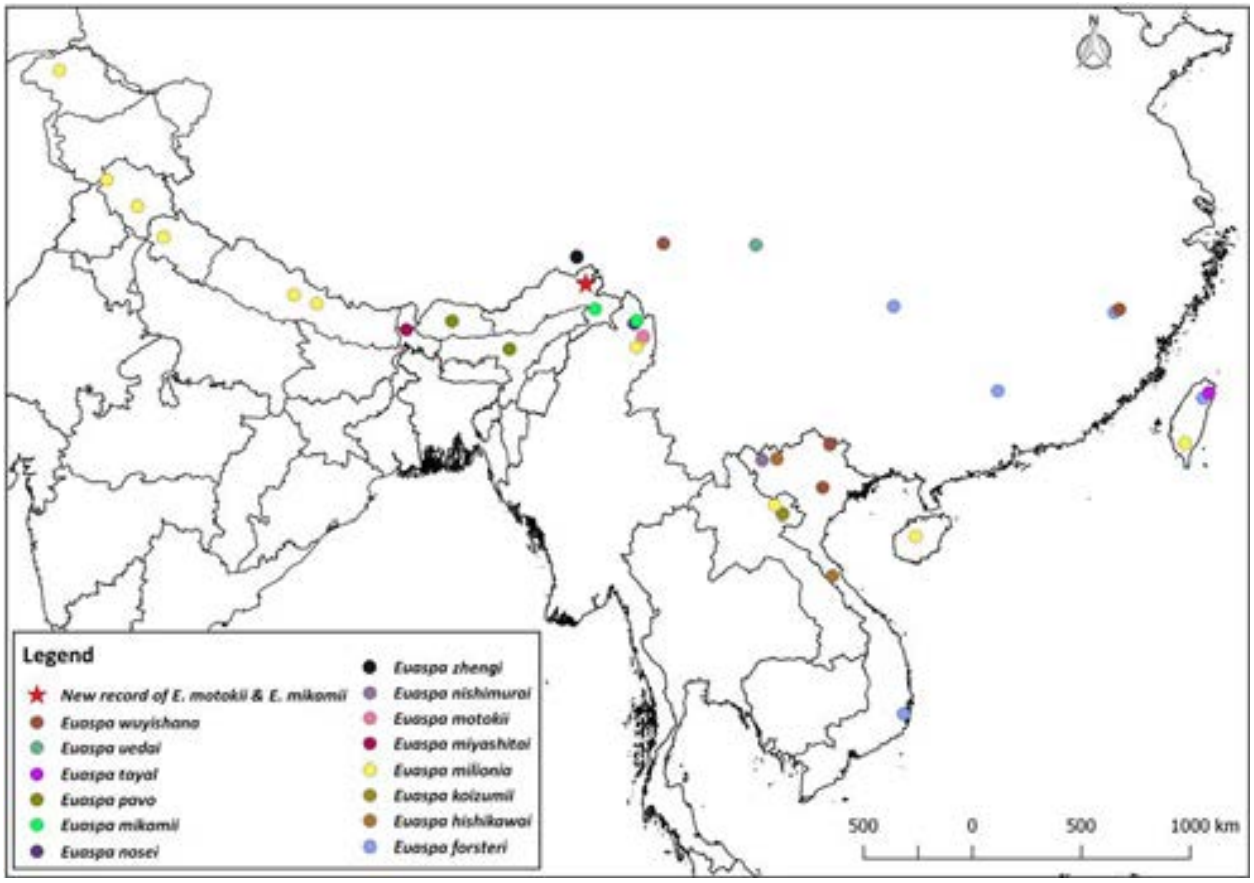

Figure 1. Distribution of 14 species of the genus *Euaspa*, including current records of *E. motokii* and *E. mikamii* from Arunachal Pradesh (★) (data extracted from Huang 2016 and Zhuang et al. 2018).

Image 1. Dihang Valley in Arunachal Pradesh, India.

***Euaspa mikamii* Koiwaya, 2002**

E. mikamii Koiwaya, 2002, *Gekkan-Mushi*, 377: 2–8

Type locality: Lohit in Arunachal Pradesh, India.

Distribution: Northeastern India and Myanmar.

Diagnostic: *Euaspa mikamii* can be identified from all other congeners by the following characters: forewing with median orange marking most extensive among other congeners (Image 2ia); hindwing subtornus is more produced than other *Euaspa* species; median and postmedian greyish-white fascia of underside of hindwing is almost straight, thus forming a somewhat V-shaped mark (Image 2ib).

Current record: On 7 June 2017, a single individual was photographed (Image 2i) at around 11.15h near Anini (28.784^{0}N & 95.876^{0}E; 1369m) in DDBR, Arunachal Pradesh, within a patch of subtropical broadleaved evergreen forest.

Remarks: *Euaspa mikamii* was described from 2400m in Lohit District, Arunachal Pradesh, based on a specimen collected on 19 July 1991 (Koiwaya 2002). After its description, it was only reported from Mapanput (27.332^{0}N & 97.883^{0}E) in Kachin State, Myanmar (Zhuang et al. 2018). A detailed literature review on the butterflies of Arunachal Pradesh revealed no record of the species from India since its description in 2002 (Horsfield & Moore 1857; Evans 1912; South 1913; Gupta & Shukla 1988; Radhakrishnan 1988; Varshney & Shukla 1988; Borang et al. 2008; Gogoi 2012; Sondhi & Kunte 2014, 2016; Singh 2015, 2017; Singh & Das 2016). Thus, the current record extends the distribution of the species in the eastern Himalaya and is the second record from India.

Conclusion

The centre of origin of zephyrus hairstreaks is in the temperate zone of eastern Asia (between 25°N and 35°N), whereas the maximum species richness and endemism are reported from the Sino-Himalayan and Sino-Japanese sub-regions (Zhuang et al. 2018). Among zephyrus hairstreaks, the species of *Euaspa* are particularly distributed in the Himalaya and eastern

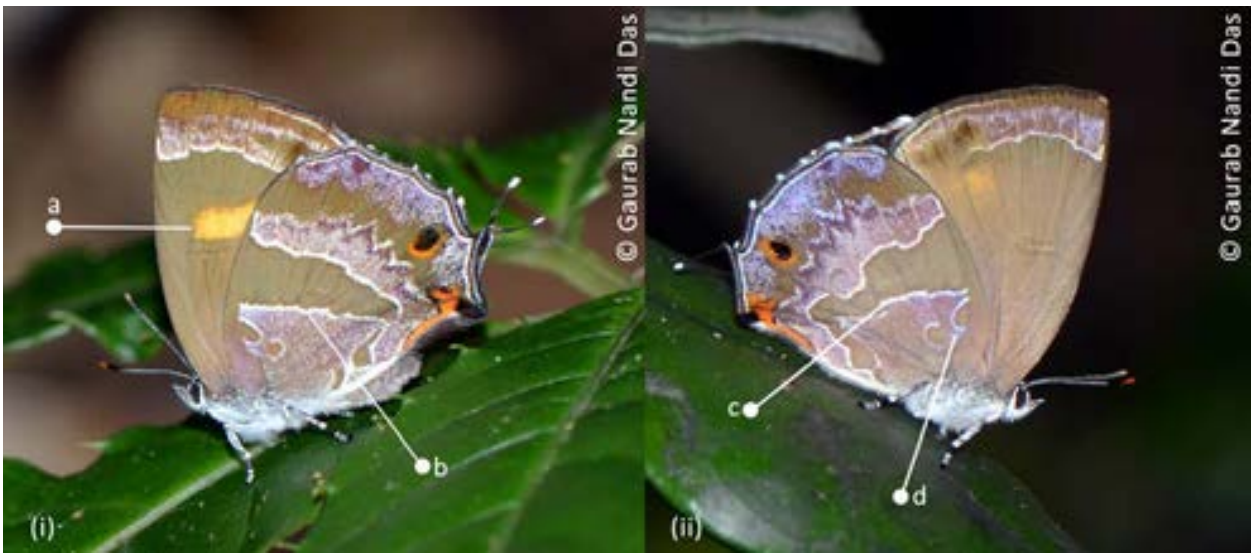

Image 2. *Euaspa* species recorded from Dihang-Dibang Biosphere Reserve in Arunachal Pradesh, India: i - *E. mikamii* | ii - *E. motokii*.

Asia. The knowledge on the geographical distribution and ecology of the Himalayan zephyrus species are in the nascent stage due to incomplete investigations and explorations, except some records and early-stage studies from the Himalaya (Saito 2017). The current record of two *Euaspa* species from Arunachal Pradesh reveals the need for systematic sampling in the remotest corners of the Indian Himalayan region.

An extensive survey in all major forest types is essential to unveil the complete distribution of the elusive and under-recorded butterflies in the region. Ongoing sampling in DDBR uncovers the typical habitats where these two species were recorded under development activities. Thus, prioritizing community engagement is mandatory for regular assessment and habitat monitoring, endorsing environmental awareness for long-term viability and conservation of this enigmatic group of butterflies.

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PLATINUM OPEN ACCESS

First report of the Australian gall midge *Actilasioptera tumidifolium* Gagné, 1999 (Diptera: Cecidomyiidae) from Andaman Islands, India

Duraikannu Vasanthakumar [1] & Radheshyam Murlidhar Sharma [2]

[1,2] Zoological Survey of India, Western Regional Centre, Akurdi, Pune, Maharashtra 411044, India.
[1] duraivasanthakumar@gmail.com (corresponding author),
[2] rmsharma13@gmail.com

The genus *Actilasioptera* belonging to the tribe Lasiopterini was erected by Gagné in 1999 and includes six species (Gagné & Jaschhof 2017). *Actilasioptera* species differ from other Lasiopterini in having the ovipositor modified for piercing plant tissue, the whole ninth segment being glabrous, and nearly devoid of setae (Gagné 1999). Among the six species of *Actilasioptera*, five (*A. coronate*, *A. pustulata, A. subfolium*, *A. tuberculate*, and *A. tumidifolium*) are known from Australia and one (*A. falcaria)* from Indonesia. All the species of this genus have been known to cause galls on the leaves of the mangrove plant genus *Avicennia* (Avicenniaceae) (Gagné & Jaschhof 2017).

While identifying the collections of gall midges deposited in the Zoological Survey of India, Pune, we came across some specimens belonging to *Actilasioptera tumidifolium* Gagné. Here we present the first record of this species from the Andaman Islands, India, and a brief diagnosis and images of its diagnostic characters.

Gall midges were reared from the leaf galls of the mangrove species *Avicennia marina* from the Andaman Islands during a survey from 1981 to 1983 by one of the authors (RMS). Adults were dissected and mounted on microscope slides in Canada balsam. The slides were examined under Compound Microscope (Meopta 25210). Identification of midges was done with the help of literature (Gagné 1999; Sharma 2009).

Material examined: Ent 10/189, 12.vii.1982, India, Lohabari, South Andaman, 11.590^{0}N & 92.612^{0}E, 11m, coll. R.M. Sharma. Four males and 3 females dissected and mounted on slides (deposited in Zoological Survey of India, Western Regional Centre, Pune).

Distribution: Queensland in Australia (Gagné 1999) and Andaman Islands in India (new record).

Diagnosis: Antenna with scape cylindrical, longer than wide; pedicel spheroid; flagellomeres 12, each longer than wide, first and second flagellomeres connate (Image 1A); palpus 1-segmented with several setae (Image 1B). Tarsal claws with sinuous basal tooth; empodia as long as claws (Image 1C); wing length 2.5mm; R5 about 0.7 length of the wing (Image 1D); genitalia robust; gonocoxite cylindrical; gonostylus abruptly tapered beyond bulbuous base, setulose; hypoproct bilobed posteriorly; aedeagus narrow and curved ventrally at apex (Image 2A). Ovipositor modified for piercing plant tissue, the whole ninth segment glabrous and nearly devoid of setae (Image 2B).

Gall: Leaf gall. Discoid, lenticular, compressed, solitary or paired but never agglomerate, glabrous, rugose, pouch gall nearly equally visible from both sides of leaf blade, dark yellow when young but copper red as

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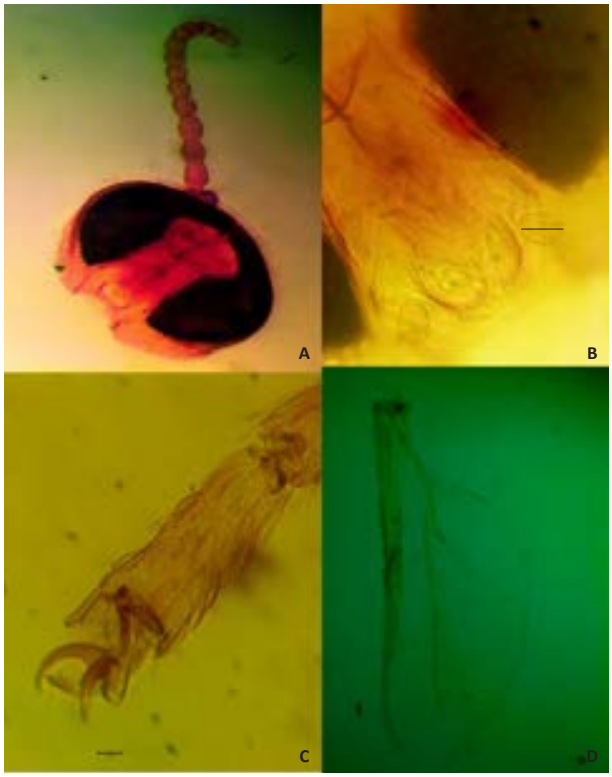

Image 1 . *Actilasioptera tumidifolium*: A—Antennae | B—Palpi (scale=0.24mm) | C—Tarsal claw (scale=0.1mm) | D—Wing (scale=0.5mm). © D. Vasanthakumar.

grown old, indehiscent, persistent; gall cavity unilocular containing many larvae inside, pupation inside the gall cavity, pupal period 3–4 days; larvae parasitized by chalcids; ostiole hypophyllous, minute, usually 5–14 exit holes seen in a mature gall. Size 5–12 mm in diameter. Number of galls per leaf varies from one to four (Sharma 1989).

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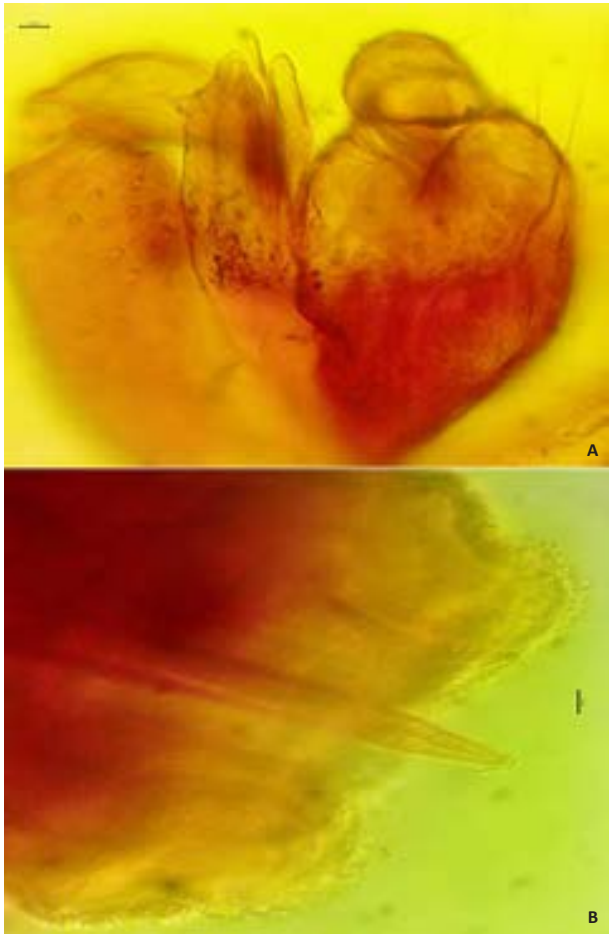

Image 2. *Actilasioptera tumidifolium*: A—Male genitalia | B—Ovipositor (scale–0.1mm). © D. Vasanthakumar.

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New record of Blanford's Fox *Vulpes cana* (Mammalia: Carnivora: Canidae) in central Oman: a connection between the northern and southern populations

Taimur Alsaid [1], Abdulrahman Aluwaisi [2], Sultan Albalushi [3], Zahran Alabdulsalam [4], Said Alharsusi [5] & Steven Ross [6]

[1–6] Office for Conservation of the Environment, Diwan of Royal Court, P.O. Box 246, Muscat, Sultanate of Oman.
[1] tatsaid@diwan.gov.om (corresponding author), [2] abdull0085@gmail.com, [3] smsalbalushi@diwan.gov.om, [4] zasabdsalam@diwan.gov.om, [5] super.harsusi@gmail.com, [6] steveross.oce@gmail.com

The Blanford's Fox *Vulpes cana* is a small (1kg) canid associated with arid, rocky habitats within mountains and wadis (also known as valleys or dry river beds, fills up after heavy rain) (Geffen 1994). The species has a wide distribution ranging from Afghanistan in the north to Egypt, Pakistan, and Yemen in the south (Geffen 2004). Due to the inaccessibility of its habitat and its strictly nocturnal activity patterns, the species was only recently recorded from Dhofar in southern Oman (Harrison & Bates 1989). It is also known to be present in the northern Hajar Mountains of Oman (S. Ross & Spalton, pers. obs. 2002) and in the United Arab Emirates (Smith et al. 2003). In Oman, the Blanford Fox populations in the Hajar Mountains and the southern Dhofar Mountains are separated by approximately 650km of largely flat gravel desert and sand dunes. Although the IUCN Red List has mistakenly indicated that this area is within the Blanford Fox's range in Oman (Hoffmann & Sillero-Zubiri 2015), the area contains very little suitable habitat and there has been no published records or any indication through local sightings or Bedouin folklore of the presence of the species in the central regions of the country. Here we describe a small isolated population of the Blanford's Fox found within Al Wusta Wildlife Reserve (WWR) in central Oman.

The study area is located in and around WWR, Al Wusta Governorate, Oman (Fig. 1). The WWR consists of a flat limestone gravel desert, which is bounded by the Huqf escarpment, consisting of large boulders and cliffs of up to 100m. The escarpment drops to the Huqf depression and the coastal hills (Massolo et al. 2008; Fig. 1). The area is hyper-arid, receiving approximately 13.7mm of rainfall per annum (PACA 2018); however, water is often available in winter from fogs arising from the Arabian Sea and moving through the area. The WWR is home to several large mammal species and a mesocarnivore guild including Wildcat *Felis silvestris lybica*, Red Fox *Vulpes vulpes*, Rüppell's Sand Fox *V. rueppellii*, and Honey Badger *Mellivora capensis*. Small mammal prey includes Arabian Spiny Mouse *Acomys dimidiatus* and Gerbils *Gerbillus* spp. The vegetation cover is very sparse in the region between periods of rainfall. Plant cover mostly consists of trees of *Prosopis cineraria*, *Acacia ehrenbergiana*, and *A. tortilis* and scattered perennial shrubs and grasses.

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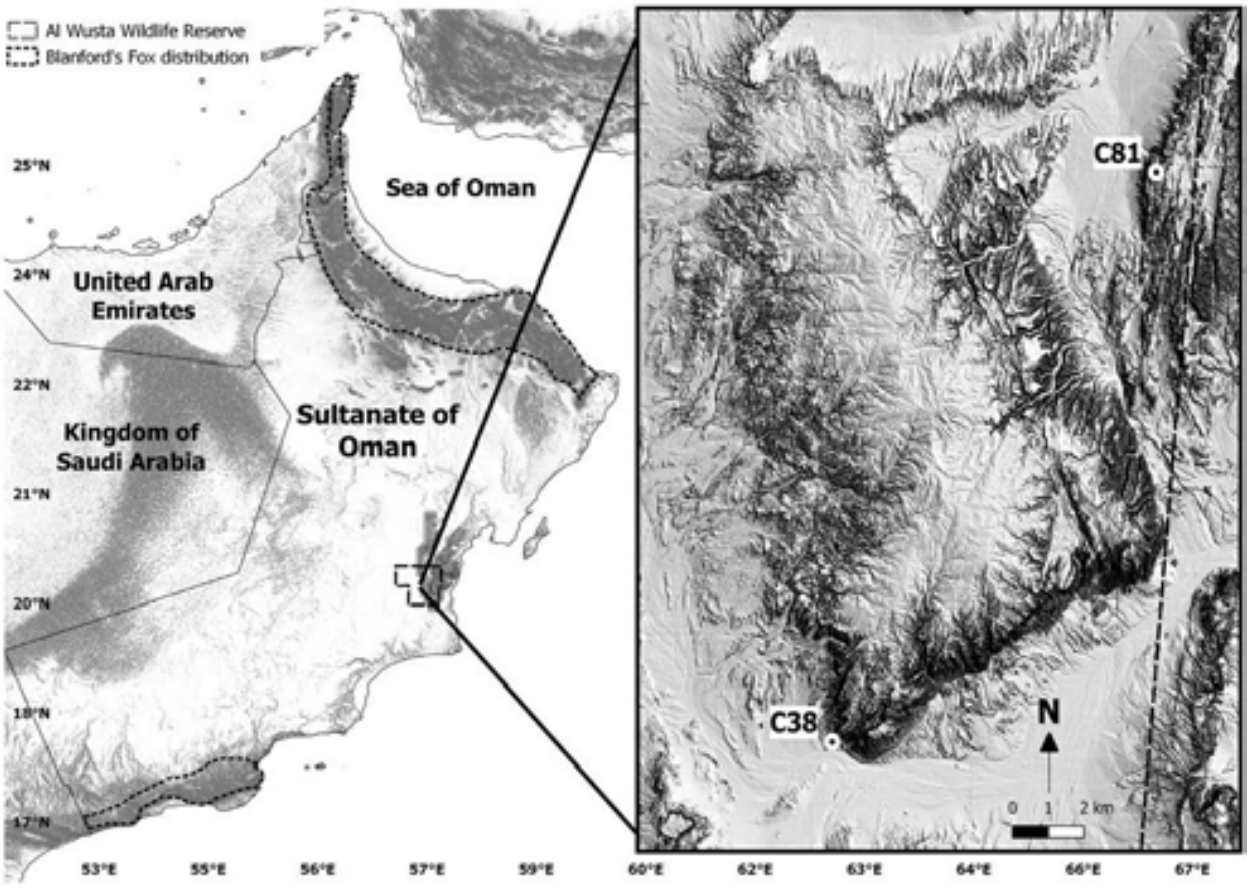

Figure 1. The study area, camera trap sampling grid, Al Wusta Wildlife Reserve (left), and the locations of the two cameras that captured the Blanford's Fox within the study area (right) in Oman.

From May 2016 to August 2018, we set up 169 camera traps (Bushnell Trail Cams) throughout the study area as part of an ongoing study of mammalian biodiversity. Cameras were set for a minimum of six months, using a 5km x 5km grid to systematically sample the study area (Fig. 1). Cameras were installed at a height of 0.25–0.75 m above the ground to survey large and medium mammals, using normal infrared sensor sensitivity to trigger a three-photograph burst with a 5s-delay between captures. The camera traps sampled an area of approximately 5,400km^2 (Fig. 1). We successfully retrieved data from 153 cameras, set for a total of 53,524 trap nights. Camera trap images of Blanford's Fox were easily distinguished from that of Red Fox and Rüppell's Sand Fox using a combination of snout and ear shape and length, body proportions, and the presence of a bushy tail with a black tip.

Blanford's Fox was detected at only two camera locations, C38 and C81 (Fig. 1). C38 was set for 529 days on a small flat area on a mountain surrounded by large boulders and small cliffs, 50m above a large valley. C38 detected Blanford's Fox on four occasions (Image 1a) and also photographed Nubian Ibex, Arabian Gazelle *Gazella arabica*, and Red Fox. C81 was set for 537 days on a mountain pass within a small mountain range consisting of large boulders, cliffs, and wadis. C81 detected Blanford's Fox on three occasions (Image 1b) and also photographed Nubian Ibex, Arabian Gazelle, Red Fox, and domestic camel *Camelus dromedarius*. All images of Blanford's Fox were taken in the dark between 17.56h and 03.36h.

Despite a very large camera trapping effort and a large sampled area, all of the cameras that photographed Blanford's Fox were in a small cluster, covering an area of approximately 46km^2. Although further research is required, the low and clustered incidence of Blanford's Fox sightings in the study area suggests that the population may be both small and isolated. It is difficult to know the reason for the populations' small size, as very few people use the area. It could be a combination of poor habitat quality and intraguild competition with Red Fox, which is a relatively common species in the

Image 1. Camera trap images of Blanford's Fox in Al Wusta Wildlife Reserve, Oman: a - camera c38 | b - camera c81.

area. There is also the possibility that the population is a remnant from dispersing Blanford's Foxes from the northern or southern populations, located approximately 310km and 330km away, respectively.

Blanford's Fox is classified as Least Concern by the IUCN Red List and is not a priority species for conservation. The small and isolated nature of the WWR population, however, warrants special regional protection. As the area is close to the port of Duqm, which is currently experiencing rapid industrial development, the area is likely to see increased disturbance in the near future. Fortunately, the identified population exists inside WWR, making protection of the population less complicated. A special protection and research plan should be initiated to protect and understand the origin and relationship of the population with both Dhofar and Hajar Mountain Blanford's Fox populations.

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