Journal of Threatened Taxa

Building evidence for conservation globally

Platinum Open Access

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

10.11609/jott.2021.13.3.17847-18058
www.threatenedtaxa.org

26 March 2021 (Online & Print)
Vol. 13 | No. 3 | Pages: 17847–18058

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

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

Host
Zoo Outreach Organization
www.zooreach.org

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Caption: The Grey-handed Night Monkey *Aotus griseimembra* recorded inside a tropical rainforest remnant known as "Ciénaga de la Tortuga" in the Magdalena river valley of the department of Caldas, Colombia. © Leonardo Mendieta-Giraldo.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17847–17855
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6077.13.3.17847-17855
#6077 | Received 01 May 2020 | Final received 05 March 2021 | Finally accepted 07 March 2021
PLATINUM OPEN ACCESS

ARTICLE

Decline of White-throated Bushchat *Saxicola insignis* Gray J.E. & J.R. Gray, 1847 (Aves: Passeriformes: Muscicapidae) in Nepal: implications on its global status

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Abstract: The White-throated Bushchat, also known as Hodgson's Bushchat, is a long-distance migratory and specialist grassland bird categorized as Vulnerable on the IUCN Red List. In Nepal, White-throated Bushchat winters in the lowlands, and has been primarily recorded in large Phantas (=open plains of grassland). We present the population status of the species in Shukla Phanta, the largest continuous lowland grassland in Nepal that is known to hold the largest wintering population of White-throated Bushchat in the Indian subcontinent. Our 2013–2014, 2016–2017, and 2017–2018 winter surveys for White-throated Bushchat followed the same method used in the 1997–1998 and 2007 surveys in Shukla Phanta for comparable assessment of the status of the species. Our study provided overwhelming evidence that the species has undergone a steep decline over the last two decades (probability of 92% for a decline greater than 5% per year). Shukla Phanta is dominated by the species' preferred habitat of *Imperata cylindrica*, *Narenga porphyrocoma*, and *Saccharum bengalensis*. Grassland patches managed through controlled burning leaving enough reeds for perches, grazed at medium level of intensity by wildlife and within close distance to water were found to support higher numbers of White-throated Bushchat. Given the observed steep decline in the largest known wintering population of the species and similar declines observed in the wintering populations in India, its status warrants uplisting to Critically Endangered, and we recommend an urgent review of its global status.

Keywords: Abundance, Hodgson's Bushchat, IUCN Red List, lowland grassland, Shukla Phanta, status, winter visitor.

Editor: Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Baral, H.S., T.R. Bhatt, B.K. Dhakal, D. Chaudhary, H.K. Yadav, L.P. Poudyal, H. Chaudhary, P.R. Joshi, C. Inskipp & R. Amin (2021). Decline of White-throated Bushchat *Saxicola insignis* Gray J.E. & J.R. Gray, 1847 (Aves: Passeriformes: Muscicapidae) in Nepal: implications on its global status. *Journal of Threatened Taxa* 13(3): 17847–17855. https://doi.org/10.11609/jott.6077.13.3.17847-17855

Funding: Darwin Initiative, UK Government and ZSL provided funding for this study.

Competing interests: The authors declare no competing interests.

For **Nepali abstract, Author details** & **Author contribution** see end of this article.

Acknowledgements: This study was conducted as part of Darwin Initiative Project / UK Government Grant No 22009. We thank the Department of National Parks and Wildlife Conservation for granting permission to execute the project. This study formed a part of the above project. We would like to thank Mr Uba Raj Regmi, Dr Bhagawan Raj Dahal, Dr Naresh Subedi, Dr Gitanjali Bhattacharya, and Dr Jonathan Baillie for their support.

INTRODUCTION

White-throated Bushchat *Saxicola insignis* J.E. & G.R. Gray, 1847 is a grassland specialist and one of the poorly known *Saxicola* species; Jerdon's Bushchat *Saxicola jerdoni* is the other little known species that is recorded in Nepal (Urquhart 2002; Clement & Rose 2015). *Saxicola insignis* is listed under the Vulnerable category in the IUCN Red List due to its declining population throughout its restricted range (BirdLife International 2018). The global population is estimated to be between 3,500 and 15,000 individuals based on assessment of recent records and surveys carried out by BirdLife International (2019); however, more recent information indicates the global population to be significantly lower.

White-throated Bushchat breeds locally in alpine or subalpine rocky meadows and scrub in the mountains of Mongolia and adjacent parts of Russia, and migrates southward across the Himalayan mountain range to winter in the Gangetic plain of the Indian subcontinent (Ali & Ripley 1987; Gombobaatar et al. 2011; BirdLife International 2018). It has been recorded on passage in northern and western China, including Tibet. The species' wintering range is restricted west from Haryana (Ambala), east through Uttar Pradesh, Uttarakhand and Bihar to northern West Bengal and Assam (Manas) through the Nepal Terai and Jalpaiguri duars (Ali & Ripley 1987; BirdLife International 2018). As a long-distance migratory bird facing threats, the species has been listed in Appendix II of Convention on Migratory Species (CMS 2018).

In Nepal, White-throated Bushchat has been recorded in six localities: Chitwan (winter visitor and passage migrant), Kathmandu Valley (passage migrant), Koshi (Koshi Tappu and Koshi Barrage, winter visitor and passage migrant), Lumbini Farmscape (winter visitor and passage migrant), Banke National Park (winter visitor) and Shukla Phanta (winter visitor and passage migrant) (Fig. 1) (Inskipp et al. 2016). In 1998 the wintering population in Nepal was estimated to be 110 individuals (Baral 1998). Shukla Phanta in the far southwestern Nepal has been reported to support the largest wintering population of the species in the region (Baral 1998; Yadav 2007; Thakuri 2012). There have been very few observations of the species in the other localities in Nepal (Inskipp et al. 2016). Given its restricted wintering habitats, continuing habitat loss and observed declining population since 2007 it has been classified as Endangered in the Nepal bird Red Data Book (Inskipp et al. 2016, 2017). The species has also been recommended to the Government of Nepal to be listed as a protected species under the National Parks and Wildlife Conservation Act (Baral 1998; Inskipp et al. 2016).

Habitat loss and degradation, due to overgrazing, cutting and burning of grassland, is the major threat to the White-throated Bushchat in Nepal (Baral 1998; Yadav 2007; Thakuri 2012). Most of the suitable grassland habitats for the species are now confined to protected areas, and outside protected areas very little lowland grasslands remain in Nepal (Baral 2001).

This study was undertaken to update the status of the species in its major grassland sites in the Nepal Terai, and assess its implication on the species' global status. It formed part of a wider species monitoring project in Shuklaphanta National Park.

MATERIALS AND METHODS

Study area

Shukla Phanta with an area of 34km^2 is the largest lowland grassland area in Nepal, located within Shuklaphanta National Park (ShNP 2017, Fig. 2, Image 1). The grassland consists primarily of *Saccharum bengalensis*, *S. spontaneum*, *Imperata cylindrica*, *Narenga porphyrocoma*, and *Desmostachya bipinata*. The grassland also harbors a number of threatened species including the globally Critically Endangered Bengal Florican *Houbaropsis bengalensis*; the Endangered Bengal Tiger *Panthera tigris,* Hog Deer *Axis porcinus*, & Hispid Hare *Caprolagus hispidus*; and the Vulnerable Jerdon's Babbler *Chrysomma altirostre*, Swamp Francolin *Francolinus gularis*, Greater One-horned Rhinoceros *Rhinoceros unicornis*, & Swamp Deer *Rucervus duvaucelii*. Shuklaphanta National Park has

Image 1. Habitat of White-throated Bushchat, Shuklaphanta, Nepal.

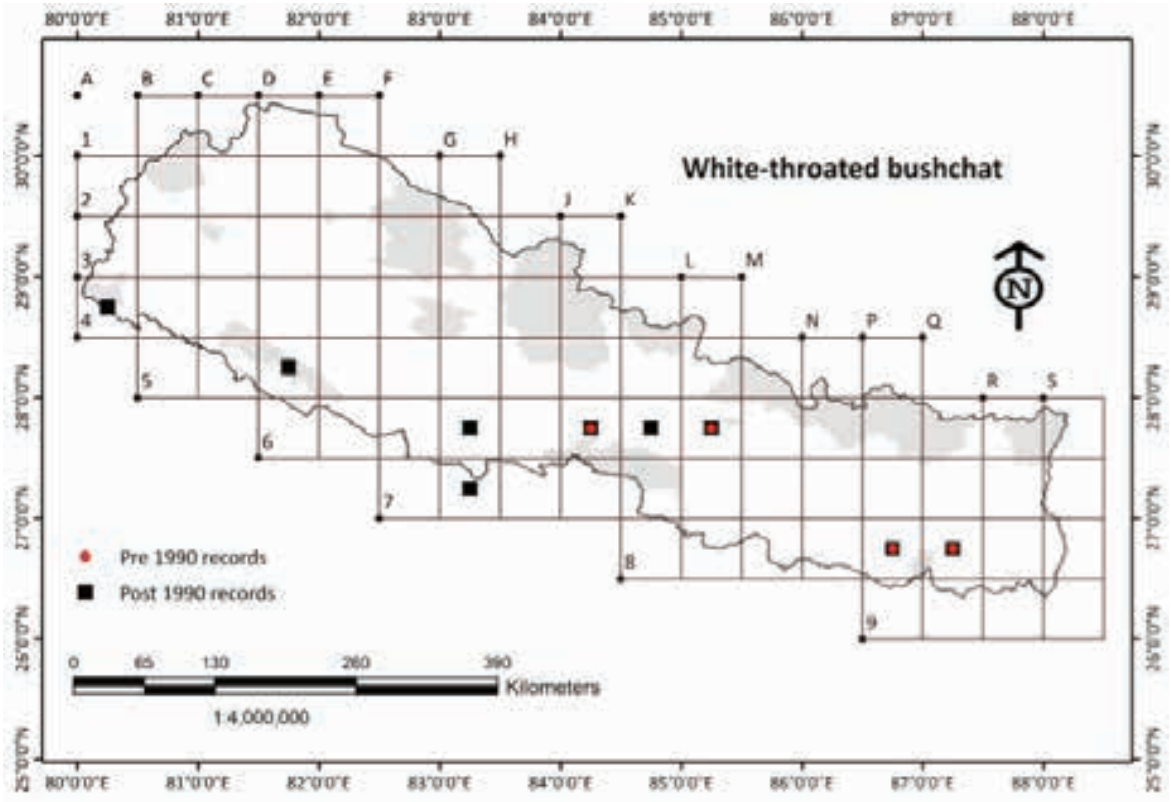

Figure 1. White-throated Bushchat distribution in Nepal based on pre and post 1990 sighting records (Source Inskipp et al. 2016).

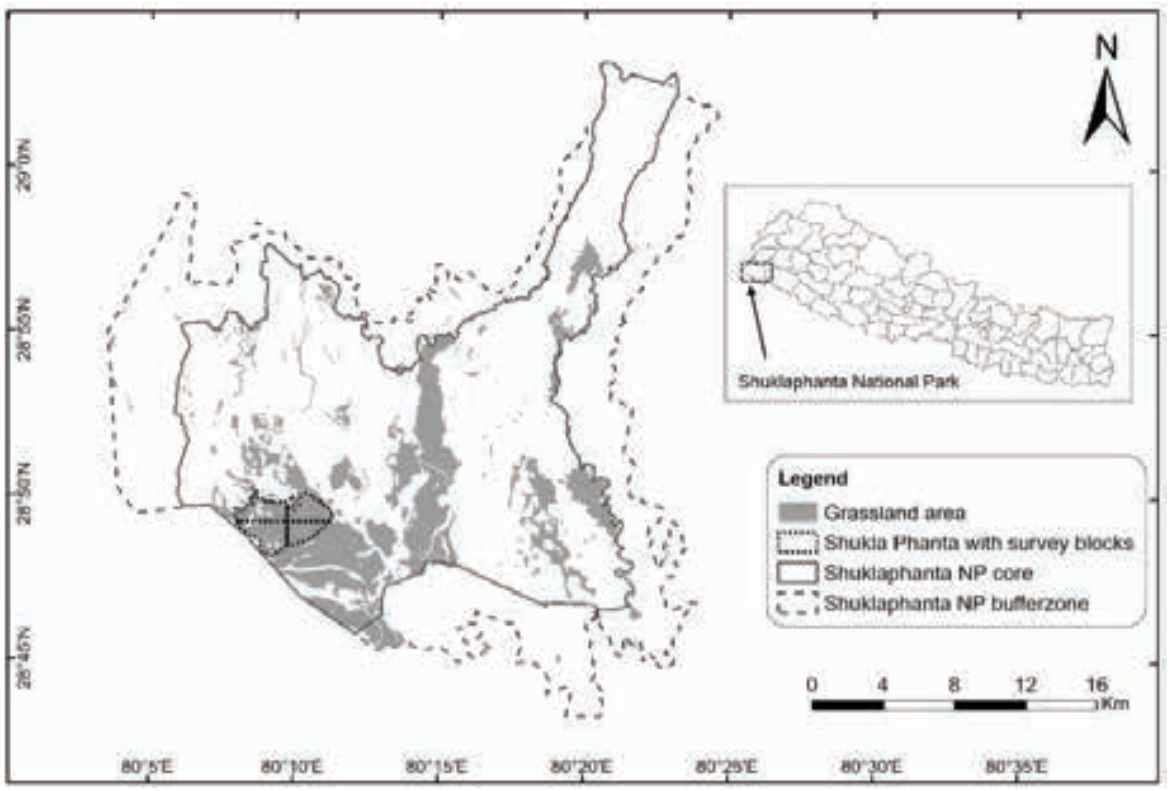

Figure 2. Location of Shukla Phanta grassland within Shuklaphanta National Park in the far southwestern corner of Nepal. The surveyed area is also shown.

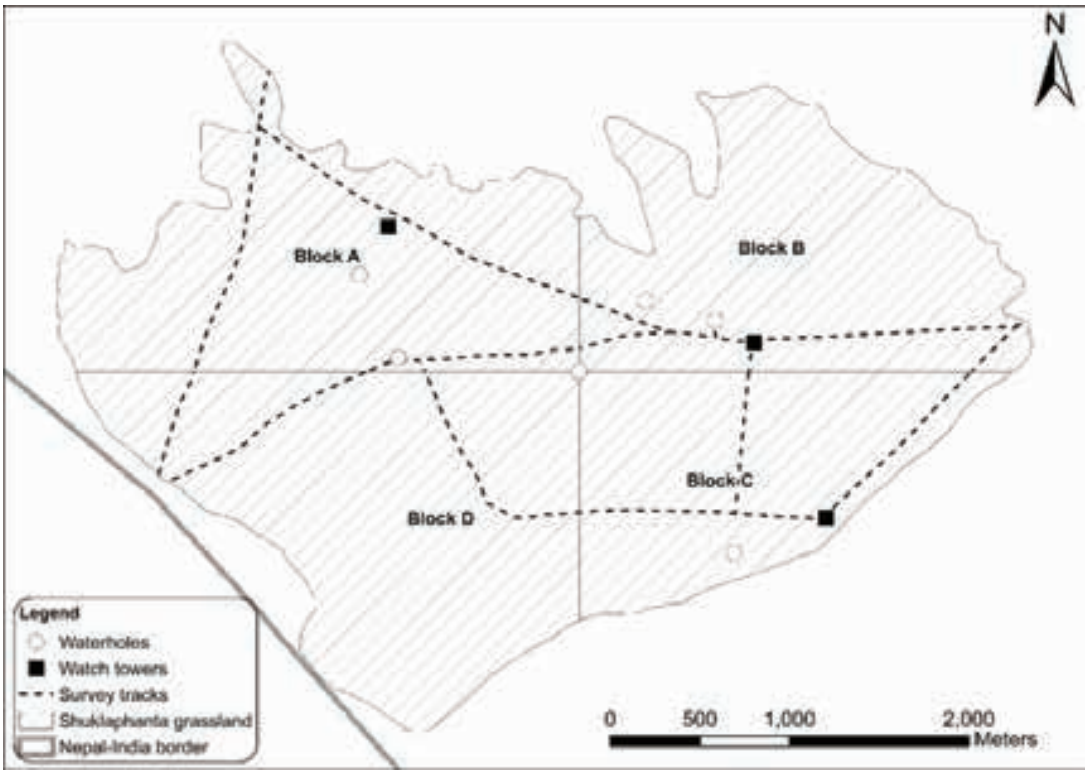

Figure 3. Shukla Phanta study area with survey blocks and tracks.

a sub-tropical monsoonal climate with three distinct seasons, monsoon (July–October), cool-dry (November–February) and hot-dry (March–June).

Field methods

Systematic surveys for the White-throated Bushchat (Image 2) were conducted over three winters in Shukla Phanta: winter of 2013–2014, 2016–2017, and 2017–2018. The line transect survey method was the same as that used in the previous 1997–1998 and 2007 surveys. Other smaller grasslands in Shuklaphanta National Park (Singhpur, Radhapur, Sundari Phanta) were also searched for the species as part of the reconnaissance at the beginning of each survey. Field ornithologists were consulted to verify the information collected on bird sightings, their numbers and for their perceptions on the status of the species (T.R. Giri & D.R. Joshi pers. comm. 2014).

A total of 11 trained individuals, which included technical national park staff, non-profit field workers, and freelance field ornithologists participated in the surveys. Prior to each survey, participants were familiarized with the identification of White-throated Bushchat in the field, and determining its sex based on morphological characteristics (Grimmett et al. 2000). Participants were also provided with a guidebook to help with bird species identification. Two of the participants had also taken part in the previous 1997–1998 survey.

The study was conducted in a portion of the larger Shukla Phanta grasslands where the species had been recorded in the past and the area also covered in the previous surveys. The 11.7km^2 survey area was divided into four blocks (Fig. 3). Surveys were carried out along 15.3km of motorable trails (Table 1) between 06.00–09.00 h when the species is most active. Each survey was carried out for a total of 16 days over a 3-month period. Three observers scanned grassland and other habitats for White-throated Bushchat using Opticron 8 x 42 binoculars and telescopes (Nikon FIELDSCOPE ED50 and Swarovski ATS 60 HD), from an open-back jeep travelling at 10km per hour. On sighting the species, the vehicle was stopped and data recorded on a data form. The recorded data included the GPS location, date and time, number of birds, their sex (except for immatures), and their activities (feeding, perching). The grassland condition was recorded as uncut and unburned, uncut and burned, and cut and burned. Dominant grass species were recorded, based on visual observation, along with grazing intensity (low, medium, high). Distance to the nearest water body and grass sward height were also recorded. Double counting was minimized by surveying all blocks at the same time and double-checking records

Table 1. Summary of combined survey effort for the White-throated Bushchat in the Shukla Phanta study area over the 2013–2014, 2016–2017, 2017–2018 wintering seasons.

Survey block	Area (km²)	Total number of days surveyed	Total length of motorable trails surveyed (km)
A	3.12	16	5.05
B	2.89	16	3.67
C	2.15	16	3.32
D	3.52	16	3.26

Image 2. White-throated Bushchat, Shuklaphanta, Nepal.

at the end of each survey.

Data analysis

Observations of White-throated Bushchat were tabulated in Microsoft-Excel. Species maximum count for each survey period were compared with the 1997–1998 survey results and the percentage of White-throated Bushchat sightings in the three grassland conditions, in the three grassland grazed intensities, and distance to water bodies were calculated.

We assessed population trend by regressing natural log of counts against survey years (1997–1998, 2005–2006, 2013–2014, 2016–2017, 2017–2018) (Baral 1998; Yadav 2007). The slope of the regression provides an estimate of the instantaneous growth rate (*r*) (Caughley 1977). A significant positive slope implies an increasing population and a negative slope implies population decline, while a slope of zero implies a stationary population (Caughley 1977). To provide further insight we used Bayesian analysis (Crome et al. 1996). We assumed a flat prior and treated the scaled likelihood curve as the posterior probability. On this basis, we calculated the probability of no decline (trend > 0), a small decline (-0.05 < trend < 0) and a steep decline (trend < -0.05) by calculating the area under the respective parts of the curve.

RESULTS

A total of 63 White-throated Bushchat sightings was recorded over a total of 16 days in the three surveyed seasons. In the 2013–2014 wintering season, a maximum of seven individuals was recorded on the 20 and 25 March, while a minimum of two individuals was recorded on 22 April. In 2016–2017 season, a maximum of six individuals was recorded on the 14 January, and a minimum of two individuals on 12 January. Similarly, in 2017–2018 season, a maximum of six individuals was recorded on 18 March, and a minimum of one individual on 19 and 20 March (Table 2). Male White-throated Bushchat (n=37) were observed more frequently than females (n=26). No birds were recorded in the smaller grassland patches during the reconnaissance surveys.

The species was only observed in grassland habitat dominated by *Imperata cylindrica*, *Saccharum spontaneum or Narenga porphyrocoma* with a sward height greater than 30cm. More than two-thirds of the Shukla Phanta grasslands are covered with dense stands of taller *Narenga porphyrocoma* and *Saccharum bengalensis* either single species or mixed, and in the

Table 2. Maximum and minimum sighting records of White-throated Bushchat in the wintering survey periods of 2013–2014, 2016–2017, and 2017–2018.

Survey winter period	Number of individuals sighted in a day	Date
2013–2014	7 (maximum)	20 March 2014 and 25 March 2014
	2 (minimum)	22 April 2014
2016–2017	6 (maximum)	14 January 2017
	2 (minimum)	12 January 2017
2017–2018	6 (maximum)	18 March 2018
	1 (minimum)	19 March 2018 and 20 March 2018

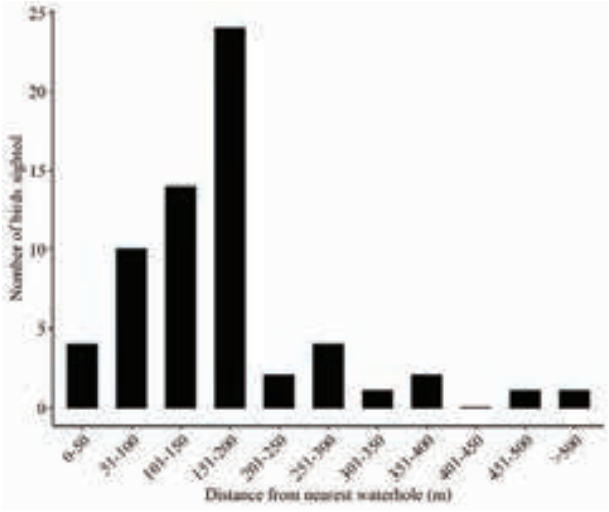

Figure 4. Number of White-throated Bushchats sighted at different distance range from nearest water body.

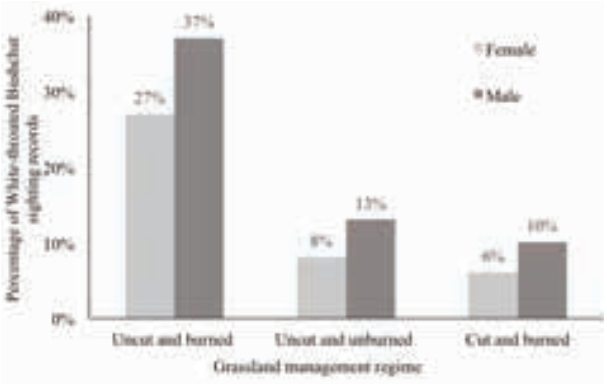

Figure 5. Percentage of White-throated Bushchat sightings within three different grassland management regimes.

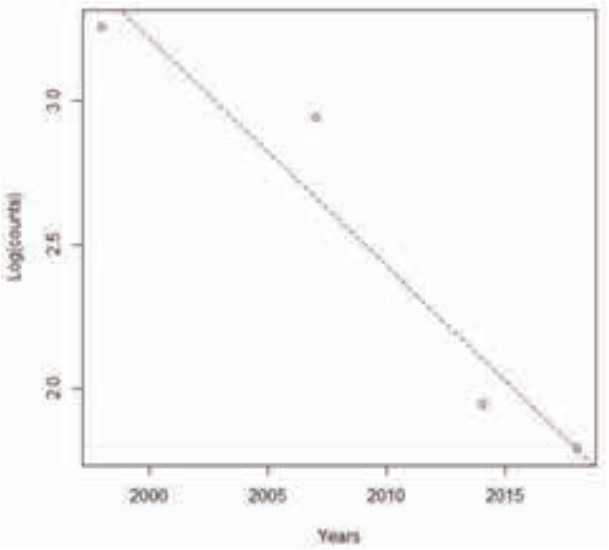

Figure 6. White-throated Bushchat population trend in Shukla Phanta based on surveys carried out over two decades.

southeastern corner *Phragmites karka* monostand forming the largest contiguous *Phragmites* marshland of Nepal. Even during the fire season, most of these wetter patches of grasslands remain unburnt or only partially burnt. Previous surveys have already established that these *Phragmites* marshland habitats are not used by White-throated Bushchats.

There was significant correlation between sighting of the birds and distance from the nearest water body (χ^2=20.86, df=2, p=0). Nearly half of the sightings (45%; n=28) were within 150m from a water source while more than 90% of the sightings (n=58) were made within 300m from a water source (Fig. 4).

The highest number of White-throated Bushchat sightings (63%; n=40) were in uncut but burned grassland patches followed by uncut and unburned patches (21%; n=13), and cut and burned patches (16%; n=10) (Fig. 5). In terms of grazing intensity, 57% of White-throated Bushchat sightings (n=36) were in medium grazed grassland patches while nearly 30% (n=19) were in low grazed patches and remaining 13% (n=13) of the sightings were in high grazed patches.

Population trend analysis based on maximum number of 26, 19, 7, 6, and 6 individuals counted during 1997–1998, 2005–2006, 2013–2014, 2016–2017, and 2017–2018 surveys revealed an average 8% (R-squared=0.92, 95% CI=-14.9% to -1%) per year decline (Fig. 6). The Bayesian analysis showed a 92% probability of a steep decline with a probability of only 7% of small decline (Fig. 7).

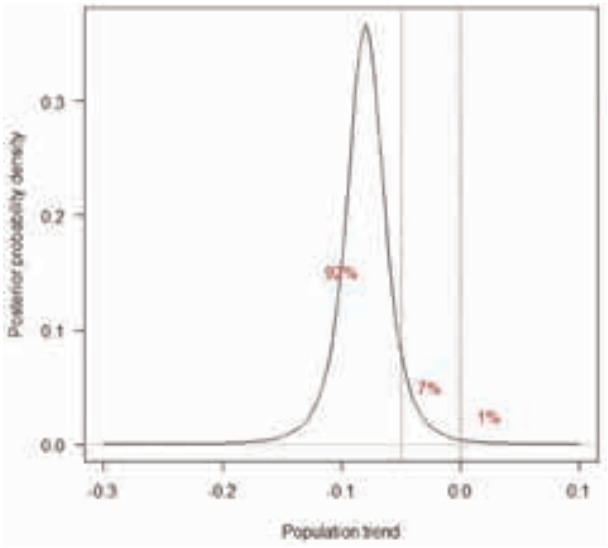

Figure 7. Probability distribution of White-throated Bushchat population decline in Shukla Phanta based on surveys carried out over two decades.

DISCUSSION

Most of the global wintering population of White-throated Bushchat occurs in northern India and southern Nepal (Ali & Ripley 1987) and along Indo-Bhutan landscape, with a single record from Bhutan (BirdLife International 2018). The species' subtropical riverine grasslands remain the most threatened habitats in the Indian subcontinent (Baral 2001; Grimmett et al. 2011; Rahmani 2012), and also one of the most threatened ecoregions of the world (Olson et al. 2001). The rapid range and population decline of this globally threatened species are of serious concern.

This study has shown that White-throated Bushchat has very specific habitat requirements in its wintering grounds. We observed that the species utilizes uncut and burned grassland more than uncut-unburned and cut-burned grasslands. We did not observe any cut but unburned grassland areas in the study site; almost always if areas are cut then they are burned. This preference for uncut and burned grassland could be due to the presence of a few unburnt reeds and some partially burnt reeds that act as perching posts, and the exposed ground patches that allow the birds to see insect movement (Baral 1998, 2001). Additionally, the clearings enable increased activity of soil arthropods due to higher heat absorption by dark ashes deposited on the ground (Baral 2001). In contrast, the least number of individuals were seen in cut and burned grasslands, possibly due to lack of suitable perches. The study has also shown that medium-grazed grasslands support a higher number of the species, which may be due to the few open patches for the birds to see ground-dwelling insects as well as ample number of standing reeds as perches (Kleijn 2010). Very few bushchats were recorded in grasslands with high grazing intensity, possibly due to absence of suitable perches. Although illegal, livestock grazing is one of the biggest problems in Shuklaphanta National Park, the Shukla Phanta grassland is located in the core of the park and is grazed by wild herbivores only.

The study also found a strong association of species sightings with water holes and wet areas. A high percentage of individuals was recorded in close proximity to water bodies. Water and flooding are associated with the formation of early stage successional grasslands (Baral 2001). In the known wintering grounds of White-throated Bushchat in Nepal, these early stage successional grasslands usually comprise *Sachharum spontaneum* and *Imperata cylindrica* which provide high quality physical structure of habitat, such as suitable perch height and sufficient open ground. This habitat may also provide the right type of food in ample amount.

The lowland Terai grasslands are a valuable economic resource for local communities and are important for conserving biodiversity as they support a wide variety of flora and fauna (Baral 2001). Although Shukla Phanta is recognized as the stronghold for White-throated Bushchat in Nepal, the number of birds recorded has dramatically declined since systematic surveys began in 1997. Based on this decline, we have already listed the species as Endangered on the Nepal bird Red List, and a proposal has been submitted to the Government of Nepal for inclusion in the list of protected birds under National Parks and Wildlife Conservation Act (Inskipp et al. 2016).

Composition of grass species and consequently physical structure of the habitat is an important factor in the occurrence and abundance of White-throated Bushchat in its wintering range (Baral 1998, 2001). The Terai lowland grassland ecosystem is very fragile and responds to even small-scale manipulations or modifications (Baral 2001). There have been significant changes in the composition of the grasslands in lowland Nepal over the last two decades. Many shorter grassland species habitats have been either lost through development outside protected areas or through succession in protected areas. Shorter grass species such as *Imperata cylindrica* and *Saccharum spontaneum* that make up the suitable habitat for the White-throated Bushchat and several other globally

threatened species such as Bengal Florican *Houbaropsis bengalensis*, are being taken over by coarser and taller *Narenga porphyrocoma*, *Themeda arundinacea*, and *Saccharum bengalensis* (Baral 2001). Although the underlying mechanism of the habitat change is yet to be fully understood, it is likely that in addition to existing practices of grassland burning, grass collection and grazing, changes in herbivore populations in protected area and altered climate events due to global warming have contributed to the rate of succession.

White-throated Bushchat has also been recorded from outside the protected areas in lowland Nepal. These are mostly of single isolated birds, however, and it is unlikely that a large wintering population occurs outside protected areas in Nepal. Recent records from India also indicate population decline in known wintering grounds, with only a single or a few birds recorded (BirdLife International 2018). The species has been observed in several new localities in India, which might be primarily because of a larger number of people observing birds in recent years. Unlike more secretive species, White-throated Bushchat is an obvious species, further minimizing the chances of under-recording especially during targeted surveys.

The decline of the wintering population of the species is perhaps also a reflection of a declining breeding population and threats along the migration paths. Habitat loss at breeding sites and environmental conditions along migratory path (including food availability, predation and disturbance) may be contributing to the severe decline of the population within a short span of time (Gombobaatar et al. 2011; BirdLife International 2018). Impact of climate change to this species is unknown, some of its migratory patterns may have been affected by climate change.

Globally, White-throated Bushchat is classified as 'Vulnerable' on the IUCN Red List based on its restricted geographical coverage, small and declining population (BirdLife International 2018). This assessment, however, is based on an outdated global population estimate of 2,500–9,999 mature individuals compiled in 2001 by Birdlife International and other limited information available for the species (BirdLife International 2018). Clement & Rose (2015) have suggested that the global population may be well under 1,000 based on the species decline across Nepal and India.

The current observed decline of the largest wintering sub-population of the species meets the Critically Endangered Criterion A2a (≥80% population reduction observed/expected through direct observation in the largest wintering sub-population) and C2a (maximum of 6 individuals observed in the largest wintering sub-population and assuming all other previously known smaller wintering sub-populations to have less than 50 individuals), along with observed declines at other sites and threats reported at breeding sites and along migratory routes. Therefore, we propose an immediate global re-assessment. Earlier literature also recommended up-listing the species global status from Vulnerable to Endangered or Critically Endangered (Baral 1998; Clement & Rose 2015).

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Nepali abstract: सेतोकण्ठे धिप्सी विश्वमै दुर्लभ र संकटको अवस्थामा रहेको लोपोन्मुख र लामो दूरीको बसाइसराई गर्ने चरा प्रजाति हो । नेपालको दक्षिणभाग तराइ मधेशका समथर भागमा रहेका घाँसेमैदानका फाँटहरूमा यो हिउँद बिताउने गर्दछ । नेपालको सबैभन्दा फराकिलो र ठूलो घाँसेमैदान शुक्लाफाँटा राष्ट्रिय निकुञ्जमा रहेको छ । यस निकुञ्जमा भारतीय उपमहाद्वीपकै सबैभन्दा बढी संख्यामा हिउँदे आगन्तुकका रुपमा यो प्रजातिको अवस्था यस शोधपत्रमा चित्रण गरिएको छ । ईस्वी संवत १९९८ र २००७ मा गरिएका सर्भेक्षणहरू संग तुलना गर्नका लागी सोही विधि र पद्धति अनुसार ईस्वी संवत २०१३ र २०१४, २०१६ र २०१७ र २०१७ र २०१८ का हिउँदमा यिनको संख्याको सर्वेक्षण गरियो । हाम्रो अध्ययनले बितेका दुई दशकमा यो प्रजातिको संख्यामा व्यापक गिरावट आएको (९२% को कुल गिरावट जुन औसतमा ५% को वार्षिक गिरावट) पाइयो । शुक्लाफाँटा घाँसेमैदान यो प्रजातिको लागी मनपर्ने शिरू खर, काँश र खडाइका घाँस प्रजातिहरूको बाहुल्यता रहेको बासस्थान हो । वन्यजन्तुबाट हुने मध्यम रुपको चरीचरन, पानी नजीकैका र नियमन गरी डढाइएका घाँसेमैदानहरू जहाँ यिनीहरूलाई आहार खोजी गर्नका लागी केही नडढेका घाँसका अग्ला डण्ठीहरू हुन्छन् यस्तो बासस्थानमा यिनको उपस्थिति बाक्लो देखियो । यस प्रजातिको अहिले सम्म थाहा पाइएको विश्वकै सबभन्दा ठूलो संख्यामा आएको गिरावटका कारण यसको विश्व अवस्थामा परिमार्जित गरी आईयूसीएन्को रातो सूचीमा अति संकटापन्न प्रजातिका रुपमा संलग्न गर्नुपर्ने देखिन्छ र सोही बमोजिम सुझाव प्रस्तुत गरिएको छ ।

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Author contribution: Hem Sagar Baral conceived, led the field work and writing of the paper including for fundraising and coordination. Tek Raj Bhatt supported fundraising, coordination as well as helped write the paper with data analysis. Rajan Amin and Carol Inskipp helped with data analysis and writing of the paper. Bed Kumar Dhakal and Laxman Prasad Poudyal facilitated field work. Dhiraj Kumar Chaudhary, Hathan Chaudhary, Hemanta Kumar Yadav and Pradeep Raj Joshi participated in the field work.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17856–17864

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

https://doi.org/10.11609/jott.5947.13.3.17856-17864

#5947 | Received 03 April 2020 | Final received 08 December 2020 | Finally accepted 17 March 2021

PLATINUM OPEN ACCESS

CONSERVATION APPLICATION

Relocation of a GPS collared conflict Sloth Bear *Melursus ursinus* (Mammalia: Carnivora) in Karnataka, India

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Abstract: The relocation of conflict bears has been a tool used widely across the United States and Canada with mixed results. It has also been used in India with Sloth Bears, though without follow-up it remains unknown how successful these relocation efforts have been. We documented the capture and relocation of a conflict female Sloth Bear from a rural area near Bangalore, Karnataka, India to Bannerghatta National Park roughly 30km away. This female bear, approximately six years old, was fitted with a VHF/GPS store-on-board collar, and her movements tracked. She did not attempt to return to her capture location but during the first two-month period after being released she did roam over an area roughly six times that of typical female Sloth Bear home range. Over the subsequent months the area over which she roamed continued to decline. She was least active mid-day and more active in the evening, night, and early morning. During her last few weeks in January, before she was killed by an explosive device just outside of the park, her movement pattern shrank considerably. The post-mortem examination showed that she had been pregnant when killed and would have given birth within the next two weeks. These reduced movements were consistent with those of periparturient female bears or potentially with a bear becoming more acclimated to her new surroundings. The relocation effort appeared successful up until the Sloth Bear was killed by poacher activity.

Keywords: Activity pattern, denning, Bannerghatta, poaching, crop raiding, reproduction.

Tamil abstract சுருக்கம்: முரண் படுகின்ற கரடிகளை இடமாற்றம் செய்வது அமெரிக்கா மற்றும் கனடா முழுவதும் கலவையான முடிவுகளுடன் பரவலாகப் பயன்படுத்தப்படும் ஒரு கருவியாகும். இடமாற்றம் முறை கரடிகளுக்கு இந்தியாவில் பயன்படுத்தப்பட்டுள்ளது, ஆனால் பின்தொடர்தல் இல்லாமல் இந்த இடமாற்றம் முயற்சிகள் எவ்வளவு வெற்றிகரமாக இருந்தன என்பது தெரியவில்லை. இந்தியாவின் கர்நாடகாவின் பெங்களூருக்கு அருகிலுள்ள ஒரு கிராமப் பகுதியிலிருந்து ஒரு பெண் கரடியைப் பிடித்து சுமார் 30 கி.மீ தொலைவில் இருக்கும் பன்னெர்கட்டா தேசீய பூங்காவுக்கு இடமாற்றம் செய்ததை நாங்கள் ஆவணப்படுத்தினோம். ஏறக்குறைய ஆறு வயதுடைய இந்த பெண் கரடிக்கு வி.எச்.எஃப் / ஜி.பி.எஸ் ஸ்டோர்-ஆன்-போர்டு காலர் பொருத்தப்பட்டிருந்தது, மேலும் அதன் அசைவுகள் கண்காணிக்கப்பட்டன. அந்தக் கரடி கைப்பற்றப்பட்ட இடத்திற்கு மீண்டும் திரும்பி செல்ல முயற்சிக்கவில்லை, ஆனால் விடுவிக்கப்பட்ட முதல் இரண்டு மாத காலப்பகுதியில், வழக்கமான பெண் கரடி வீட்டு வரம்பை விட ஆறு மடங்கு அதிகமாக அது ஒரு பகுதியில் சுற்றித் திரிந்தது. அடுத்தடுத்த மாதங்களில் அது சுற்றித் திரிந்த பகுதி தொடர்ந்து குறைந்து கொண்டே வந்தது. அது மாலை, இரவு, மற்றும் அதிகாலையில் மிகவும் சுறுசுறுப்பாக இருந்தது. நடுப் பகலில் சோர்வாக இருந்தது. ஜனவரி மாதத்தில் அதன் கடைசி சில வாரங்களில், பூங்காவிற்கு வெளியே ஒரு வெடிக்கும் கருவியால் அந்த கரடி கொல்லப்படுவதற்கு முன்பு, அதன் இயக்க முறை கணிசமாக சுருங்கியது. பிரேத பரிசோதனையில் அது கொல்லப்பட்டபோது கர்ப்பமாக இருந்தது, அடுத்த இரண்டு வாரங்களுக்குள் பிரசவித்திருக்கும் என்றும் தெரிய வந்தது. இந்த குறைக்கப்பட்ட இயக்கங்கள், பெண் கரடிகளின் இயக்கங்களுடன் ஒத்துப்போகின்றன அல்லது ஒரு கரடி தனது புதிய சூழலுடன் மிகவும் பழக்கமாகிவிட்டது. இந்த கரடி வேட்டையாடும் நடவடிக்கையால் கொல்லப்படும் வரை இடமாற்றம் முயற்சி வெற்றிகரமாக தோன்றியது.

Editor: Karin Schwartz, WildTrack, Milwaukee, Wisconsin, USA.

Date of publication: 26 March 2021 (online & print)

Citation: Arun, A.S., S. Swaminathan, Y. Pannerselvam, T.R. Sharp, S.R. Stephens, K. Satyanarayan & G. Seshamani (2021). Relocation of a GPS collared conflict Sloth Bear *Melursus ursinus* (Mammalia: Carnivora) in Karnataka. *Journal of Threatened Taxa* 13(3): 17856–17864. https://doi.org/10.11609/jott.5947.13.3.17856-17864

Funding: None.

Competing interests: The authors declare no competing interests.

For **Author details** & **Author contribution** see end of this article.

Acknowledgments: The authors wish to express sincere thanks to the Karnataka Forests Department and officials of Bannerghatta National Park for their complete support and co-operation during the entire study.

INTRODUCTION

Sloth Bears *Melursus ursinus* are among the least studied bear species in the world and therefore one of the least understood (Garshelis & Steinmetz 2015). They are presently listed as Vulnerable on IUCN's Red List (Dharaiya et al. 2016), and as a Schedule 1 species under the Indian Wildlife Protection Act of 1972. The continued deterioration and fragmentation of habitat outside of protected habitats, where it is thought that the majority of Sloth Bears persist, is presently one of the greatest threats to the species (Dharaiya et al. 2016). The recent and complete extirpation of this species from Bangladesh highlights the concern that fragmented Sloth Bear populations are at risk (Islam 2013). Unfortunately, Sloth Bear-human negative interactions are relatively common and often take the form of bear attacks (Rajpurohit & Krausman 2000). For these reasons, it is imperative to explore viable options for handling 'problem' bear situations, other than simply dispatching the 'problem' bear. The relocation of 'problem' bears is one potential option.

The relocation of 'problem' American Black Bears *Ursus americanus* and Grizzly Bears *Ursus arctos horribilis* has been used as a management tool across North America for decades with mixed success (Linnell et al. 1997). Relocation has also been used in India with 'problem' Sloth Bears, though the success or failure of this management tool has not been well documented. A 'problem' bear is generally defined as a bear that has been involved in repeated bear incidents. A 'bear incident' is defined as an occurrence that involves a human-bear conflict or episodes (Skrbinšek & Krofel 2015). A human-Sloth Bear conflict usually means a Sloth Bear attacked a person in a defensive manner or behaved aggressively towards people, though it can also mean the bear was involved in crop raiding. The objective of relocation is to move a 'problem' bear to a new area where they are less likely to become engaged in negative interactions with humans. The relocation of a 'problem' bear is generally considered successful if the bear is not involved in subsequent incidents. Success, however, is often at least partially dependent on whether the bear returns to the capture site. Return rates tend to decrease as the relocation distance increases. Return rates are also lower for juvenile bears rather than adult bears (Rogers 1986; Landriault et al. 2009).

Sloth Bears, while generally not attracted to garbage, have conflicts with humans in the form of crop-raiding and attacks. While crop raiding is not a major problem for this species throughout much of its range, attacks are. Sloth Bears are renowned for their aggressive behavior toward humans (Burton 1856; Anderson 1957; Rajpurohit & Krausman 2000). While a Sloth Bear's attack motivation is exclusively defensive, the attacks can inflict serious injuries to the victim and might result in the victim's death (Rajpurohit & Krausman 2000; Bargali et al. 2005; Sharp et al. 2020). Unfortunately, Sloth Bear attacks are relatively common in India and affect hundreds of people annually (Rajpurohit & Krausman 2000; Bargali et al. 2005; Debata et al. 2016; Garcia et al. 2016; Dhamorikar 2017; Singh et al. 2018; Sharp et al. 2020). Given the large number of attacks that occur annually and the vulnerable status of this species (Dharaiya et al. 2016), it is reasonable to consider different management options for 'problem' bears, including relocation; however, there are no data to suggest how successful these relocations in India have been. Is the mortality rate high? Do relocated Sloth Bears attempt to return to their prior location as Grizzly Bears and American Black Bears sometimes do? In short, is relocation a useful management tool for this species?

A female Sloth Bear, believed to have attacked several people in a village roughly 30km from Bannerghatta National Park, was trapped for relocation. Permission was granted to release the bear back to the wild in Bannerghatta National Park with a GPS (store-on-board)/VHF collar. Given the paucity of data on Sloth Bear relocation efforts, as well as Sloth Bear movement and general ecology, the results of these efforts, though based on a single bear, offer valuable insights. This bear was tracked using the VHF transmitter after being released into Bannerghatta National Park. After six and a half months, she was killed by an explosive device illegally set for Wild Boars *Sus scrofa*. At this point, the collar was retrieved, and the store-on-board data downloaded. A post-mortem of the Sloth Bear showed that she had been pregnant when killed. Based on the morphometry and the weight and developmental size of the two fetuses, the female bear would have likely given birth sometime within the following seven to ten days. Very little is known about Sloth Bear breeding in the wild; therefore, movement patterns were also analyzed with respect to those of a periparturient Sloth Bear.

Study Area

Bannerghatta National Park encompasses roughly 264km^2 of protected habitat (Fig. 1). The terrain is hilly with elevations ranging 1,245–1,634 m. The valleys are predominantly made up of deciduous forest, while the hillsides and higher elevation areas are covered in

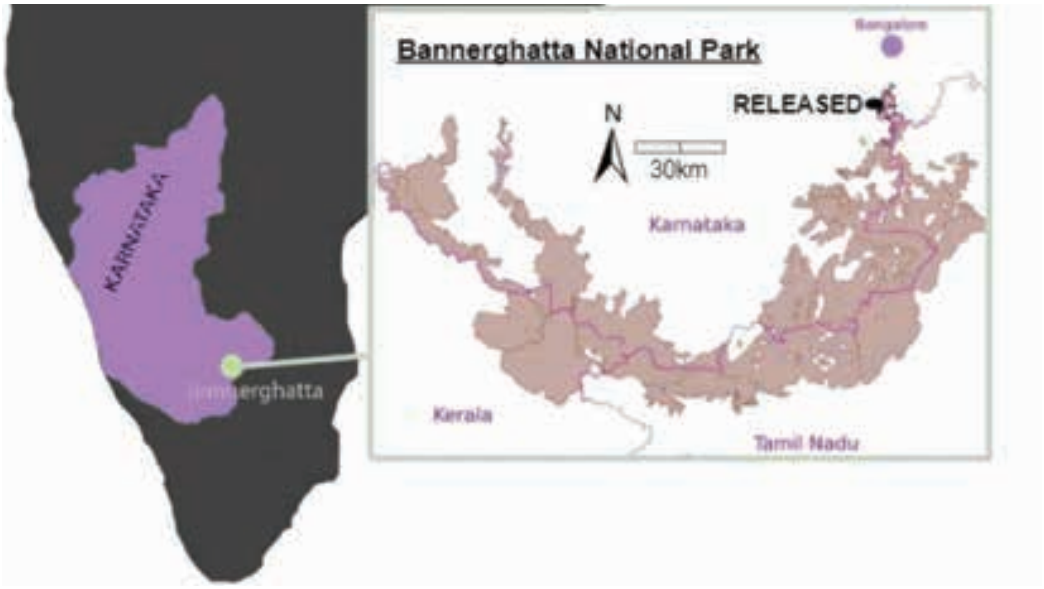

Figure 1. Bannerghatta National Park location within India, and the northeast-most section of the park (inlet map) where the Sloth Bear was released and GPS points were collected.

scrubland. The temperature in the park ranges from an average of 15°C in the winter to an average of 30°C in the summer, and it gets between 625 and 1,607 mm of rainfall annually (Ramachandra & Setturu 2019). The Suvarnamukhi River is the largest perennial river running through the park.

The southern end of Bannerghatta National Park connects to the Talli Reserve Forest and Bilikal Forest. The park also functions as part of an important Asian Elephant *Elephas maximus* corridor which also connects to the Biligirirangana Hills and the Sathyamangalam Forest. The park not only contains Sloth Bears and elephants, but other large mammals including Leopards *Panthera pardus*, Sambar *Rusa unicolor*, and occasionally even Bengal Tigers *Panthera tigris*. Medium and small mammals that live in the park include Dholes *Cuon alpinus*, Golden Jackals *Canis aureus*, Indian Porcupines *Hystrix indica*, and Indian Pangolins *Manis crassicaudata*. Many species of birds and reptiles also occur in the park including Peafowls *Pavo cristatus*, Mugger Crocodiles *Crocodylus palustris*, and Rock Pythons *Python molurus*.

MATERIALS AND METHODS

A young adult female Sloth Bear was trapped at night near a village, roughly 30km from Bannerghatta National Park, on 17 March 2017 using a barrel trap baited with honey and fruit. The bear was taken to a remote enclosure at the Wildlife SOS, Bannerghatta Bear Rescue Centre and was given a general health check, and a blood sample was collected, to make sure she was fit to be released back into the wild. She was kept in isolation from other bears, and human interaction was kept to a bare minimum in order to prevent any habituation behaviors. Permission was eventually granted by local authorities to release her in Bannerghatta National Park. The bear was fitted with a Veltronic Aerospace Vertex store-on-board GPS/VHF collar before being released at 07.20h on 30 June 2017. To get a general idea of her movement, the bear was tracked daily, homing in on the pulsed radio signals from the VHF transmitter in the collar, using a receiver and directional antenna. The tracking sessions were completed in the morning, roughly 75% of the time, and in the evening, roughly 25% of the time. When the bear was found dead, we collected the collar and downloaded the GPS data for further analysis. Additionally, a post mortem was conducted on the bear, primarily to determine the general health of the bear at the time of her demise. When it was discovered that the bear had been pregnant at the time of death, we checked the progesterone levels in her blood from when she was first captured in an effort to determine with certainty whether she had been impregnated before or after she was captured. Sloth Bears have delayed implantation (Puschmann et al. 1977) which make identifying the time of copulation difficult to ascertain simply by knowing the date, or approximate date, of when the cubs were born.

We analyzed the Sloth Bear's movement and frequency of presence by splitting the GPS data points

into three time periods. These categories were chosen based on: limited telemetry data gathered before the GPS data were available, a preliminary assessment of the GPS data to note any obvious change in movement rates, and finally the estimation of when the pregnancy would have become active (when the blastocyst implanted) based on the morphometry and weight of the fetuses during the post-mortem. The first period was made up of the initial two months (30 June through 31 August), when the bear was first acclimating to its new surroundings. The second period was made up of the middle three months (01 September through 30 November), after the bear had some time to acclimate and explore her surroundings. The third period was made up of the last month and a half (01 December 2017 through 17 January 2018), in what we call the periparturient period.

We generated maps representing the Sloth Bear's movement and frequency of presence in a given area using ArcGIS Pro 2.2.1. We recorded coordinates once hourly, with 24 counts per day, and an average daily success rate of 89.7% (~2 missed points, SD: 13.7%), with 33.5% of days having all 24 points recorded and error evenly distributed across the whole sampling period. In total, 4,848 locations were uploaded from the GPS collar, with 4,289 (88.5%) non-blank recordings used for analysis over 202 days. The release period (30 June –31 August 2017) had an 87.9% overall success rate, the acclimation period (September – November 2017) had an 87.5% overall success rate, and the periparturient period (01 December 2017–17 January 2018) had a 91.1% overall success rate. We rendered hotspot representation by using the geoprocessing spatial analyst tool: kernel density, which uses the quadratic kernel function. This method creates a search radius around a point that is classified based on the sum of GPS collar counts within that circular area. Point counts of GPS locations, reported in decimal degrees, were classified into eight bins using the geometric interval method, where warmer colors progressing from red, yellow, to orange, convey high visitation\number of GPS collar counts- and greens convey little to one-time visitation. Each map's high and low densities are respective to the designated period and not standardized across the three time periods.

RESULTS

General Movement Pattern

Once released, the Sloth Bear did not appear to attempt to return to her original capture location. She stayed predominantly within the national park borders, though she did wander outside the park borders (Fig. 2). The area she utilized in six and a half months was 71.2km^2, where 54.6km^2 (77%) were within the park and 16.6km^2 (23%) were outside of the park. The furthest that she roamed beyond park borders was 2.26km to the north. She moved an average distance of 5.9km night, with a minimum of 1.0km and a maximum of 14.7km (Fig. 3). While she did move roughly the same amount from August through December, and even more during the acclimation period than during the release period (Figs. 3, 4, 5), the area over which she moved shrank as time went on. Between 30 June and 30 August, she utilized 63.8km^2 (Fig. 4), between 1 September and 31 November she utilized 31.5 km^2 (Fig. 5) and between 1 December and 17 January, during the periparturient period, she utilized a total area of 23.4km^2. (Fig. 6). In January, the last 17 days before she was killed, she moved an average distance of just over 4km a day, and over a smaller area (8.6km^2) than she had in any of the previous six months (Fig. 7).

Movement was documented south and north of the national park borders, although she eventually settled near the northern border of the park where she spent much of her time. She was photographed multiple times by the use of camera traps and appeared to be a healthy bear (Image 1). She came close to several communities but never, as far as we are aware, had any encounters of consequence with humans. She was found dead just 83m outside of the national park in a fruit orchard (Fig. 7). She had been killed by an explosive device likely set to kill Wild Boars.

24-Hour Activity Pattern

Diel activity patterns show that she was most active 22.30–04.30 h, with minor peaks at 01.00h and 03.30h, and least active 09.00–15.00h (Fig. 8). This activity pattern did not change substantially throughout the six-and-a-half months post-release. In July, when first released, she was most active 17.30–05.30 h, with activity peaks around 00.45h and 05.00h, and least active 08.00–15.30 h. In January, before her death, she was most active 20.00–05.30 h, with activity peaks at 00.00h and 03.45–04.45 h. She was least active 08.00–15.00 h. The slight changes in peak activity and inactivity during the six-and-a-half months post-release

Image 1. Collared Sloth Bear caught in a camera trap.

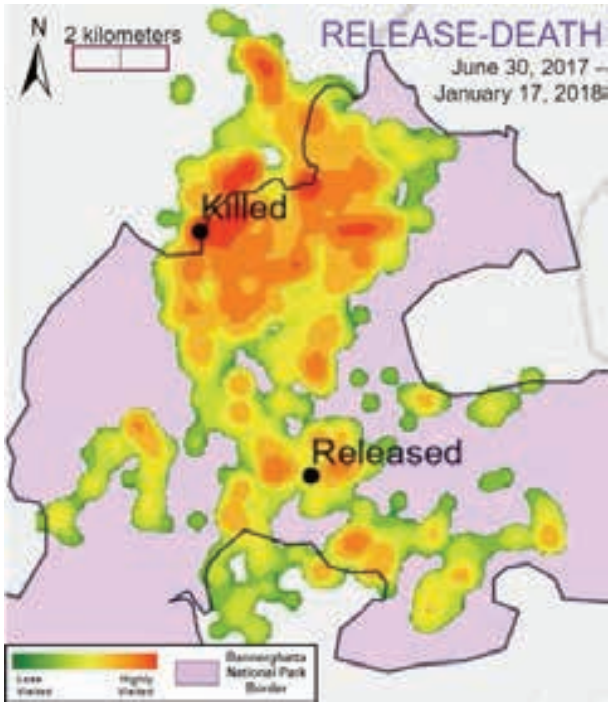

Figure 2. Area utilization by the Sloth Bear over the entire duration of release.
(Days: n= 202, GPS Point Counts: n= 4,289) Hotspot representation rendered by using the geoprocessing spatial analyst tool: kernel density, which uses the quadratic kernel function. Point counts were classified into eight bins (colored) using the geometric interval method.

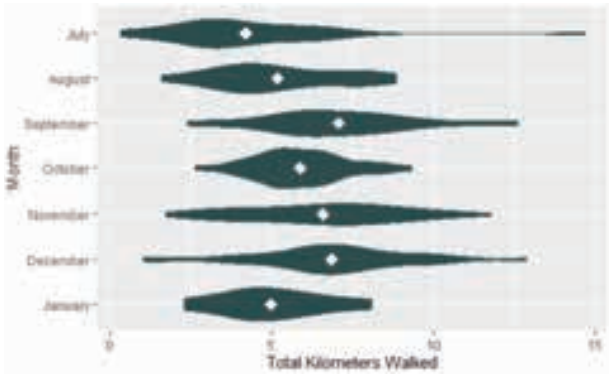

Figure 3. Violin plot of relocated wild Sloth Bear movement per day/ per month (km).
Violin plot demonstrates the range of kilometers traveled daily each month, where thicker regions convey a higher number of days spent walking that respective distance. White diamonds represent the mean value for each month (July: n=31, x̄=4207, SD = 2678; August: n=31, x̄=5198, SD = 1910; September: n=30, x̄=7068, SD = 2345; October: n=31, x̄=5887, SD = 1456; November: n=30, x̄=6576, SD = 2433; December: n=30, x̄=6854, SD = 2471; January: n=17, x̄=4993, SD = 1641).

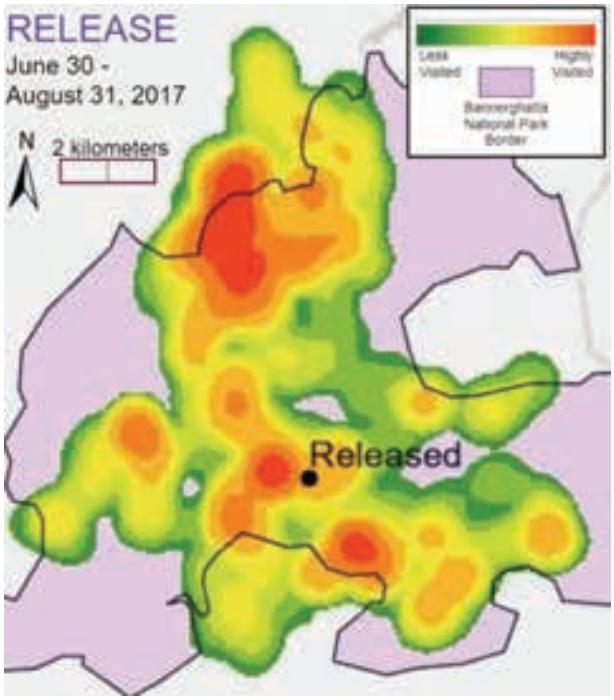

Figure 4. Area utilization by the Sloth Bear during the first two months after release. (Days: n= 63, GPS Point Counts: n= 1,329) Hotspot representation rendered by using the geoprocessing spatial analyst tool: kernel density, which uses the quadratic kernel function. Point counts were classified into eight bins (colored) using the geometric interval method.

are not correlated with slight changes in sunrise and sunset times.

Pregnancy and Denning

Necropsy revealed that the Sloth Bear had been pregnant with two cubs. The fetuses were 14 and 15 cm in length, and weighed 60 and 67 g, respectively. We attempted to discern whether she had been impregnated before or after her release by checking progesterone levels in the blood that had been drawn after capture; however, we were unsuccessful due to: 1) lack of access to a baseline of blood progesterone levels in pregnant Sloth Bears, and 2) the delayed implantation in Sloth Bears may cause a delay in raising progesterone levels,

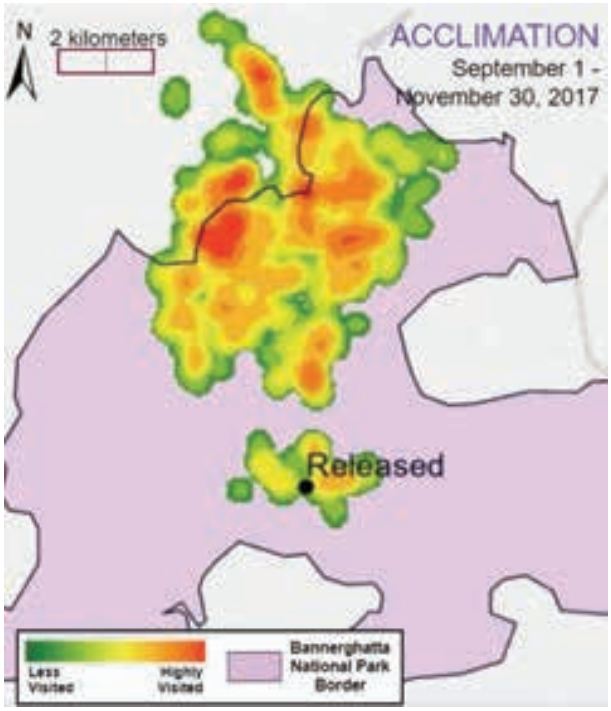

Figure 5. Area utilization by the Sloth Bear during months 3, 4 and 5 in Bannerghatta NP. (Days: n= 91, GPS Point Counts: n= 1,911) Hotspot representation rendered by using the geoprocessing spatial analyst tool: kernel density, which uses the quadratic kernel function. Point counts were classified into eight bins (colored) using the geometric interval method.

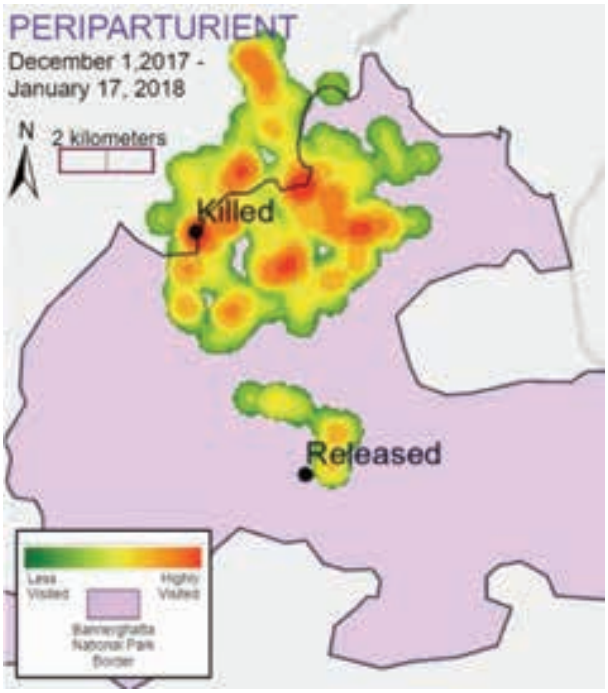

Figure 6. Area utilization by the Sloth Bear during months 6 and 7. (Days: n= 48, GPS Point Counts: n= 1,049) Hotspot representation rendered by using the geoprocessing spatial analyst tool: kernel density, which uses the quadratic kernel function. Point counts were classified into eight bins (colored) using the geometric interval method.

as seen in other bear species (Foresman & Daniel 1983).

By reviewing the data from the store-on-board GPS unit, we were able to locate multiple resting dens that she had used, including the den she had been using in January. It is likely that this latter den would have been used as the maternal den, which we describe further in the discussion. This den is located in the national park, just 60m from the boundary (Fig. 7).

DISCUSSION

General Movement Patterns

The bear did not appear to attempt to travel back to her capture site though she was only moved 30km. Translocating an American Black Bear or Grizzly Bear only 30km from the trap site would carry with it a relatively high probability that the bear would attempt to return to the trap site (Rogers 1986; Linnel et al. 1997). Sloth Bears, however, have relatively small home ranges compared to these two species and this may affect how far Sloth Bears need to be moved to reduce the likelihood they will return to their capture site area. This Sloth Bear did range over a large area inside and outside of the park borders. Given that the home range for female Sloth Bears in Nepal's Royal Chitwan National Park was estimated at 9.4km^2 (Joshi et al. 1995) and 12.4km^2 in Panna National Park (Yoganand et al. 2005), she appeared to have spent the first two months exploring her new surroundings by utilizing an area roughly six times the size of a typical home range. Interestingly, translocated Grizzly Bears in Alberta, Canada translocated outside of their bear management area of capture, were shown to initially have home ranges roughly 3.25 times that of other resident bears (Milligan et al. 2018). While the presence of other Sloth Bears may be an influencing factor in the dispersal of this individual, the population within Bannerghatta National Park is unknown. It has been speculated that this increase in movement could be linked to increased energetic costs of the bear during the relocation acclimation period (Milligan et al. 2018).

During the Sloth Bear's second three-month period, her activity only utilized an area roughly three times the size of a typical female Sloth Bear's home range, and in December an area only roughly twice the size of a typical home range. This eventual reduction in home range size is consistent with the translocated Grizzly Bears in Alberta, Canada which also saw an overall reduction in home range size as time went on (Milligan 2018). However, the reduction in the size of the Sloth Bear's home range occurred at a much faster rate than it did

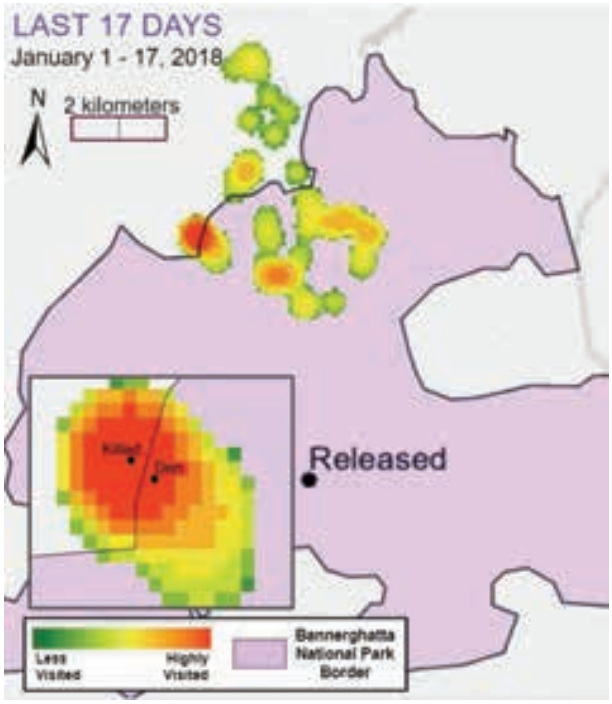

Figure 7. Area utilization by the Sloth Bear for two weeks before death in month 7. (Days: n= 17, GPS Point Counts: n= 372) Hotspot representation rendered by using the geoprocessing spatial analyst tool: kernel density, which uses the quadratic kernel function. Point counts were classified into eight bins (colored) using the geometric interval method.

for the grizzlies in Alberta. The Sloth Bear's movements in January covered an area more comparable to the estimated home range size for an adult female Sloth Bear; however, this reduction may have been more related to the fact that she was preparing to give birth, rather than a sign she had acclimated to her new surroundings.

24-Hour Activity Pattern

Sloth Bears, though occasionally diurnal, are known to be predominantly crepuscular and nocturnal (Joshi et al. 1999; Chauhan et al. 2004; Yoganand et al. 2005; Ramesh et al. 2013). Subadults and females with cubs, however, may be more active in the morning hours, which may be an attempt to avoid large male Sloth Bears or predators (Joshi et al. 1999). Given that this bear was an adult female without cubs, her activity pattern is consistent with solitary adult females from other studies.

There is a longer period of complete inactivity in November, December, and January; however, we cannot be certain whether this is related to the bear's pregnancy, the bear's acclimation to her new surroundings or an unknown variable.

Pregnancy and Denning

Sloth Bear mating generally occurs during April, May, June, and possibly July in this part of the country (Arun et al. 2018a) and cubs are born five to eight months later (Stirling 1993). This bear was captured on 17 March and therefore likely impregnated after her release. Additionally, in early July, while tracking her with VHF technology, it was noted by observing her footprints that she was in the company of a second sloth bear, which could have possibly been her mate. Though generally solitary, Sloth Bears do have a high degree of mutual tolerance for one another (Joshi et al 1999). Therefore, although we cannot be certain when she was impregnated, we believe it to be most likely that she was impregnated after her release back to the wild.

It is not surprising that the mating window in this part of India may be a little wider than previously thought as the Sloth Bear mating season varies slightly by location. In Nepal, they are known to breed May through July (Joshi et al. 1999), and in Sri Lanka, they are thought to breed year-round. If indeed, she had been impregnated post-release, it suggests low-stress levels and adjustment to her new surroundings. Whether impregnated before or after release is perhaps less important than the fact the pregnancy was moving forward. The delayed implantation capabilities of the Sloth Bear allow a female to abort and absorb the pregnancy if the animal is physically or environmentally stressed (Mead 1989; Given & Enders 1989). Therefore, the fact that the pregnancy was moving forward suggests that the sloth bear was not overly stressed in her new environment, or at least that the increased energetic costs likely associated with the relocation were still low enough for her to reproduce successfully.

Once implanted, the fetus grows to completion in roughly two months, as is the average time of gestation in bear fetuses (Tsubota et al. 1987; Quest 2001). Since we estimate she was going to give birth in late January or early February, it seems likely that her pregnancy influenced her movement patterns in December and January. It is also possible that her movements were further reduced in January due to her having identified a maternal den and associated reduction in feeding. Though Sloth Bears in captivity are known to eat within 24 hours of parturition, periparturient appetite is suppressed as parturition approaches (Arun et al. 2018a).

After the bear's death, we inspected the area where she had spent a large amount of her time in January to search for dens. We located several dens, including one within the hotspot. We believe this was likely the den

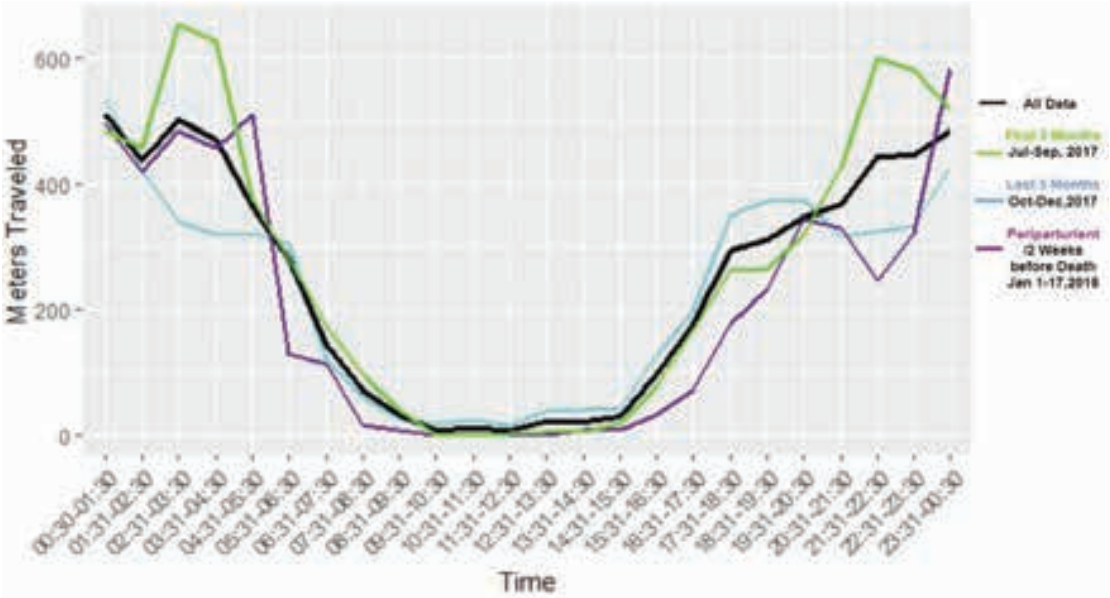

Figure 8. Sloth Bear 24-hour activity pattern per hour. Mean movement (in meters) during 1-hour time blocks for each respective time period, where black is a mean of all data (N=202), green is the mean of the first three months after release (30 June–30 September 2017, n= 93), blue is the mean of the following three months after release (1 October–31 December 2017, n= 92), and purple is the last ~2 weeks before death, during the periparturient time period where implantation is expected to have occurred (1–17 January 2018, n= 17).

in which she planned to give birth to and raise her cubs since the location was the center of her activity as she approached parturition. This den is located only 60m from the border of the national park. Because this bear spent a significant amount of time just outside the national park in an area with fruit trees, it suggests she might have intentionally chosen to den in the wilderness with food resources, in this case, a fruit orchard, nearby.

This Sloth Bear was killed near the Bannerghatta National Park border by an explosive device set by poachers most likely to hunt Wild Boars. These devices are hidden in food and detonate when bitten, thus presenting a risk to non-target species (Arun et al. 2018b). Consequently, these devices potentially pose a particular threat to wildlife, which range just outside of protected areas to forage in agricultural areas.

RELOCATION CONCLUSIONS

As stated previously, the relocation of a nuisance bear is generally considered successful if the bear is not involved in any subsequent human-bear conflicts. This is often at least partially dependent on whether the bear returns to their capture site. We believe this Sloth Bear's relocation was successful because: 1) she did not attempt to return to her capture site, 2) she was not involved in human-bear conflicts, other than occasional crop-raiding, 3) she adjusted to her new surroundings and began to establish a home range, 4) she was likely impregnated post-release, 5) her pregnancy was moving forward and we believe she established a maternal den, and 6) she was a healthy bear, based on camera trap photos of her as well as her necropsy.

Given these findings, this relocation effort was deemed a success until the bear was killed. It is also important to note that her death was not the result of a "direct" conflict situation but rather due to a negligent and illegal act not focused on sloth bears. Clearly, this is only one bear, and more documentation is needed in the future in order to determine how successful relocation efforts of Sloth Bears are; however, based on this case study, there is reason to be optimistic.

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Author contribution: Attur Shanmugam Arun—1) project leader, 2) project coordination, 3) lead on capturing and collaring sloth bear, and 4) writing and analysis. Shanmugavelu Swaminathan—1) lead field biologist, 2) capturing and collaring bear, 3) tracking bear, and 4) writing and analysis. Yogaraj Pannerselvam —1) capturing and collaring Bear 2) Tracked the bear the majority of the time, 2) Valuable Insight into bear activities. Thomas Robert Sharp—1) lead on writing and analysis, 2) background research on bear relocation of other bears species and 3) arrangement of manuscript to JoTT. Sydney Stephens—1) analysis and 2) mapping. Kartick Satyanarayan—oversight of the project and important insights into the results. Geeta Seshamani—oversight of the project and important insights into the results.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17865–17874
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6673.13.3.17865-17874
#6673 | Received 06 September 2020 | Final received 17 March 2021 | Finally accepted 19 March 2021
PLATINUM OPEN ACCESS

COMMUNICATION

Not all gone: the rediscovery of Jaguar (Carnivora: Felidae: *Panthera onca*) and records of threatened monkeys (Primates: Mammalia) in the Magdalena River Valley of Caldas Department in Colombia, a call for their conservation

Leonardo Mendieta-Giraldo [1], Sergio Escobar-Lasso [2], Esteban Grajales-Suaza [3] & José F. González-Maya [4]

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Abstract: For decades, the middle Magdalena Valley of Colombia has been a scene of heavy social and civil conflict, which have resulted on a sustained and extensive expansion of the agricultural border, dedicating most lands to extensive cattle production activities. Such extensive disturbances have led to a progressive loss and isolation of natural forests of the region, severely threatening biodiversity. A group highly susceptible to local extinction in the middle Magdalena Valley are the large and medium mammals, because they usually require large extensions of habitat with a good degree of connectivity to be able to disperse between fragments. In this sense, it is especially important to identify the last remnants of habitat that still persist in the middle Magdalena and that still are occupied by endemic and threatened mammal species. Therefore, this work confirms the presence of Jaguar *Panthera onca* and four threatened monkeys, *Ateles hybridus* (Critically Endangered), *Saguinus leucopus* (Endangered), *Cebus versicolor* (Endangered), and *Aotus griseimembra* (Vulnerable) inside an isolated remnant of tropical rainforest called "Ciénaga de la Tortuga" in the Magdalena River Valley of the department of Caldas. After 21 years of not having reliable records of Jaguars in the Caldas department, this work renews the hope for conserving this iconic species in the territory and is perhaps the last opportunity to take conservation actions to prevent the total local extinction of Jaguar in the department. This work also represents the first confirmed records of *C. versicolor* for Caldas department and the second known records of *P. onca* and *A. hybridus*. The records of *A. hybridus* are also considered the southernmost locality for the species.

Keywords: Large cats, Capuchin *Cebus versicolor*, deforestation, threatened species, endemic species, fragmentation, local extinction, Night Monkey *Aotus griseimembra*, Spider Monkey *Ateles hybridus*, Tamarin *Saguinus leucopus*.

Editor: Anonymity requested.

Date of publication: 26 March 2021 (online & print)

Citation: Mendieta-Giraldo, L., S. Escobar-Lasso, E. Grajales-Suaza & J.F. Gonzalez-Maya (2021). Not all gone: the rediscovery of Jaguar (Carnivora: Felidae: Panthera onca) and records of threatened monkeys (Primates: Mammalia) in the Magdalena River Valley of Caldas Department in Colombia, a call for their conservation. *Journal of Threatened Taxa* 13(3): 17865–17874. https://doi.org/10.11609/jott.6673.13.3.17865-17874

Funding: Regional environmental authority of Caldas department, Corporación Autónoma Regional de Caldas (CORPOCALDAS), Colombia.

Competing interests: The authors declare no competing interests.

For **Spanish abstract, Author details** & **Author contribution** see end of this article.

Acknowledgements: We want to thank the Corporacion Autonoma Regional de Caldas (CORPOCALDAS), departmental environmental authority, for the support to carry out surveys in "Ciénaga de la Tortuga". We also want to thank the owners of "Hacienda La Tortuga" for allowing us to conduct the explorations.

INTRODUCTION

The inter-Andean valley of the Magdalena River is an important area from the historical, cultural, and ecological perspectives (Mancera-Rodríguez & Rodríguez-Sánchez 2002; Fernández-Méndez et al. 2013). This valley crosses Colombia from south to north, encompassing a variety of ecoregions from Caribbean mangroves and xeric shrubs to dry and moist forests (Olson et al. 2001). Specifically, the middle Magdalena Valley is particularly composed by moist forest to the north and dry forests to the south, reason why the middle part of such area is a transition (ecotone) between those type of forests (Fernández-Méndez et al. 2013). For decades, the middle Magdalena Valley has been a scene of heavy social and civil conflict, which has resulted in extensive deforestation and expansion of the agricultural border with most lands mainly dedicated to extensive livestock farming (Fergusson et al. 2014). Such disturbances have led to a progressive loss of the natural forests of the region, threatening the natural resources base in general and biodiversity in particular (Fernández-Méndez et al. 2013; Fergusson et al. 2014). Furthermore, the unique dry and moist forests of the middle Magdalena River valley are poorly represented in the regional and local protected areas systems and are currently not represented at all within national protected areas (SIAC 2020). Nowadays, the forests that once covered the middle Magdalena have almost disappeared and the few remnants of forest that still persist are extremely fragmented and isolated (Fernández-Méndez et al. 2013). Despite these large-scale deforestation processes, the middle Magdalena River valley is still home to many endemic species, but with high risk of disappearing if appropriate conservation actions are not urgently taken (Andrade et al. 2013).

Large and medium-sized mammals are considered a group highly susceptible to local extinction, because they usually require large extensions of habitat with a good degree of connectivity to be able to disperse between fragments (Powell & Mitchell 2012). In this sense, it is especially important to identify the last remnants of habitat that still persist in the middle Magdalena and that are inhabited by endemic and threated mammal species (Castaño & Corrales 2010; Andrade et al. 2013). Therefore, the goal of this work is to report the presence of Jaguar *Panthera onca* and four threatened and endemic monkeys, the Variegated Spider Monkey *Ateles hybridus*, the Silvery-brown Tamarin *Saguinus leucopus*, the Varied White-fronted Capuchin *Cebus versicolor*, and the Grey-handed Night Monkey *Aotus griseimembra* inside an isolated remnant of tropical rainforest called "Ciénaga de la Tortuga" in the Magdalena River valley of the department of Caldas, Colombia.

MATERIALS AND METHODS

Study area

The study was carried out at a remnant of tropical rainforest called "Ciénaga de la Tortuga" (5.714°N, -74.680°W, 167 msnm, WGS 84) located close to the La Miel River mouth into the Magdalena River (Image 1). According to the ecoregions defined by Olson et al. (2001), the study area corresponds to "Magdalena-Urabá moist forests". This isolated remnant of forest has an extension of 167.3ha and a perimeter of 17.3km, located in Buenavista Village, La Dorada municipality, in the northeastern portion of the department of Caldas, middle Magdalena River valley, Colombia. The Ciénaga de la Tortuga is one of the last remnants of tropical rainforest in the region, it is immersed in lands dedicated to extensive livestock farming and is under private ownership as the "Hacienda Santa Clara" and "Hacienda La Tortuga". The rainfall regime is bimodal with the first peak of rains between March–May and the second between September–November (SIAC 2020). The major dry season occurs from June to August and there is a less pronounced dry season around December–February (SIAC 2020).

METHODS

Between September 2014 and March 2020, we carried out 11 short expeditions to the tropical rainforest "Ciénaga de la Tortuga", which together had a duration of 56 days and 327 hours (Table 1). The expeditions had two general aims, the first was to monitor the conservation status of the forest, looking for early deforestation alerts and the second was to evaluate if the forest is inhabited by endemic and threatened mammal species in order to better assess the conservation status of these forests. To record the endemic and threatened mammals, we made ad-libitum walks inside and around the rainforest which together had an extension of 28km. We used binoculars and cameras to record all individuals sighted and indirect signals (e.g., footprints, feeders, burrows, among others). The date and time of each of the sightings was recorded.

Image 1. Geographic location of the tropical rainforest remnant called "Ciénaga de la Tortuga" in the Magdalena River valley of the department of Caldas, Colombia. Ciénaga de la Tortuga is immersed in lands dedicated to extensive livestock farming and is under private ownership as "Hacienda Santa Clara" and "Hacienda La Tortuga". Note the degree of isolation of the forest patch.

Table 1. Description of ad-libitum expeditions carried out in tropical rainforest remnant called "Ciénaga de la Tortuga" in the Magdalena River valley of the department of Caldas, Colombia.

Date	Days of survey	Time of survey	Distance walked (m)
Sep-14	3	16 hours	1500
May-15	4	28 hours	2000
Aug-16	1	5 hours	500
Nov-17	3	21 hours	1500
Dec-17	2	18 hours	1000
Jan-18	7	35 hours	3500
Feb-18	9	50 hours	4500
Mar-18	9	48 hours	4500
Apr-18	6	30 hours	3000
May-18	5	36 hours	2500
Mar-20	7	40 hours	3500

RESULTS AND DISCUSSION

Jaguar *Panthera onca* (Linnaeus 1758) rediscovery for Caldas department.

The record of Jaguar was obtained through a footprint (Image 2) recorded on 7 February 2018 at 08.47h, which had all features to be consistently assigned to *P. onca* (sensu Aranda-Sanchez 2012). This is an important rediscovery of the species inside the department of Caldas, because it was believed that the Jaguar populations were locally extinct in the department (Escobar-Lasso et al. 2014). The last confirmed record of the species was made in 1999 (21 years ago) by an adult individual who was hunted by farmers as retaliation for cattle predation near the indigenous reserve "Nuestra Señora Candelaria de la Montaña", El Rosario Village, Riosucio municipality, Cauca River basin (Escobar-Lasso et al. 2014). Therefore, this work represents the second known record of Jaguar in the department, but maybe it could be one of the last individuals that still persists in the entire region.

At international level, the Jaguar is listed as Near Threatened (NT) throughout its whole distribution range (Quigley et al. 2017) but recent assessments considered 33 of 34 populations in the continent either Endangered or Critically Endangered (de la Torre et al. 2018). At the national level, the species is listed as Vulnerable (VU) by the Colombian Ministry of Environment (MADV 2017). Although most of the Jaguar's habitat has been deforested and fragmented, the species has a widespread distribution and is found in the five natural regions of the country (Andean, Caribbean, Pacific, Orinoquia and Amazon) (Quigley et al. 2017), although apparently mostly isolated an on reduced numbers (González-Maya & Jiménez-Ortega 2015; de la Torre et al. 2018). The records of Jaguars in the middle Magdalena River valley are rare and their populations are extremely fragmented due to habitat loss (Payán et al. 2016). The few populations that still persist are restricted to the north of the middle Magdalena River valley, from the south of Bolivar department in the Serrania de San Lucas (Payán et al. 2016), to the northeastern of the Antioquia department (Arias-Alzate et al. 2011) and the south-west of Santander department (Boron & Payán 2013; Boron et al. 2016). Therefore, it is important to highlight that our record is considered the southernmost locality for Jaguar in the Magdalena River valley.

Image 2. Footprints of Jaguar *Panthera onca* recorded inside a tropical rainforest remnant known as "Ciénaga de la Tortuga" in the Magdalena River valley of the department of Caldas, Colombia. © Leonardo Mendieta-Giraldo.

Variegated Spider Monkey *Ateles hybridus* Geoffroy, 1829 southernmost records.

The records of the Variegated Spider Monkey *Ateles hybridus* were obtained through direct observations on four occasions (May 2015, November 2017, January–February 2018, and March 2020). During these observations, troops of up to 10 individuals were recorded (Image 3). To date, the only known location of *A. hybridus* for Caldas department is a record made inside the Selva de Florencia National Natural Park (NNP) (Roncancio-Duque 2012). Therefore, this work represents the second known location of *A. hybridus* in the department of Caldas; however, unlike the populations recorded in Selva de Florencia NNP, the individuals of this new location are inhabiting an extremely isolated forest and without any category of conservation.

Globally, the Variegated Spider Monkey is listed as Critically Endangered (CR) under criteria A2cd+3cd given that its populations have declined at least 80% over the past 45 years (three generations) due primarily to hunting and habitat loss (Link et al. 2020). Similarly, at national level, it is listed as Critically Endangered (CR) by the Colombian Ministry of Environment (MADV 2017). In Colombia, *A. hybridus* is found from the middle valley of the Magdalena River to the northeast region of the Caribbean region, with some populations on the eastern flank of the Eastern mountain range (Hernández-Camacho 1976; de Luna et al. 2017; Link et al. 2020). Therefore, the two locations known, including these records, for the Caldas department can be considered the southernmost localities for the species.

Varied White-fronted Capuchin *Cebus versicolor* Pucheran, 1845 first confirmed records for Caldas department.

The records of the Varied White-fronted Capuchin *Cebus versicolor* (Image 4) were obtained through direct observations on six occasions (September 2014, May 2015, August 2016, December 2017, January-March–May 2018, and March 2020). Castaño et al. (2003) suggested the presence of *Cebus albifrons* in the Caldas department based on an individual deposited in the exhibit collection of the Natural History Museum of the Caldas University (without catalogue number). Such individual apparently came from the Samaná municipality, but the collection date, coordinates and other data associated with the specimen are unknown (Castaño et al. 2003). It is currently accepted that *Cebus albifrons versicolor*, classified as a subspecies by Hershkovitz (1949), should be considered a distinct species and the subspecies *Cebus albifrons adustus*

Image 3. The Variegated Spider Monkey *Ateles hybridus* recorded inside a tropical rainforest remnant known as "Ciénaga de la Tortuga" in the Magdalena River valley of the department of Caldas, Colombia. © Leonardo Mendieta-Giraldo.

and *Cebus albifrons leucocephalus* are synonyms of *C. versicolor* (Boubli et al. 2012). Based on this taxonomic discrepancy, and on the record of *C. albifrons* by Castaño et al. (2003), García-R et al. (2018) suggested the presence of *C. versicolor* inside Caldas department. Therefore, our observations of *C. versicolor* can be considered the first confirmed and reliable records of the species for Caldas department; however, it is highly likely that the species has a wider distribution in the middle Magdalena Valley of Caldas.

At international level, the Varied White-fronted Capuchin is listed as Endangered (EN) under criteria A2cd mainly due to habitat loss and illegal wildlife trade (Torre et al. 2015). At national level, however, the Colombian Ministry of Environment (MADV 2017) has not yet assessed the species. *C. versicolor* is endemic to the lower and middle parts of the Magdalena River basin of Colombia and, including these new records, the species is found in nine departments: Bolívar, Cesar, Sucre, Santander, Norte de Santander, Antioquia, Cundinamarca, Boyacá, Caldas, and Tolima (Ramírez-Chaves et al. 2016; García-R et al. 2018; This work). Therefore, it is necessary to promote studies focused on establishing a national program for conservation and management of *C. versicolor* and establish its conservation status at the national level.

New records for the Silvery-brown Tamarin *Saguinus leucopus* (Günther, 1877).

The records of the Silvery-brown Tamarin *Saguinus leucopus* (Image 5) were obtained through direct observations on six occasions (September 2014, January–March 2018, and March 2020). Many troops of *S. leucopus* have been recorded inhabiting many forest patches throughout the Magdalena River valley of the Caldas department (see Castaño et al. 2003;

Image 4. The Varied White-fronted Capuchin *Cebus versicolor* recorded inside a tropical rainforest remnant known as "Ciénaga de la Tortuga" in the Magdalena River valley of the department of Caldas, Colombia. © Leonardo Mendieta-Giraldo.

Roncancio-Duque et al. 2008; Castaño & Corrales 2010; Alba-Mejia et al. 2013; Arias-Alzate et al. 2014; Ruiz-Garcia et al. 2014; Garcés-Restrepo et al. 2016; Vélez-García et al. 2019). Even more, a species conservation and management plan was recently generated for the department in 2012 (Roncancio-Duque et al. 2012); however, the effectiveness and degree of application of such plan is unknown. This work represents a new location for the species in the Magdalena River valley of the department, which must be prioritized and considered in the present and future conservation actions due to the high degree of isolation of "Ciénaga de la Tortuga".

At the international level, the Silvery-brown Tamarin is listed as Endangered (EN) under criteria A2cd mainly due to habitat loss and illegal wildlife trade (Morales-Jiménez et al. 2008). At national level the species is listed as Vulnerable (VU; MADV 2017). This species is endemic to the country, found only in northern Colombia, between the Magdalena and Cauca rivers (Morales-Jiménez et al. 2008). In the Magdalena River valley, populations of *S. leucopus* located in the Caldas and Tolima departments represent the southernmost populations of its distribution, which are key to enable the dispersal of the species to the rest of the Magdalena River valley.

New records for the Grey-handed Night Monkey *Aotus griseimembra* Elliot, 1912.

The Grey-handed Night Monkey *Aotus griseimembra* (Image 6) records were obtained through direct observations on four occasions (May 2015, February–May 2018, and March 2020). The presence of *A. griseimembra* had already been recorded in the middle Magdalena River valley of the Caldas department, specifically in the municipality of Victoria and La Dorada (Castaño et al. 2003; Garcés-Restrepo et al. 2016; García-R et al. 2018). Therefore, this work represents a new location for the species in the Magdalena River valley of the Caldas department, which must be

Image 5. The Silvery-brown Tamarin *Saguinus leucopus* recorded inside a tropical rainforest remnant known as "Ciénaga de la Tortuga" in the Magdalena River valley of the department of Caldas, Colombia. © Leonardo Mendieta-Giraldo.

prioritized and considered in the present and future conservation actions due to the high degree of isolation of "Ciénaga de la Tortuga".

At the international level, the Grey-handed Night Monkey is listed as Vulnerable (VU) under criteria A2c due to population decreasing, being its main threats habitat loss for urban and agriculture purposes (Link et al. 2019). At the national level, it is listed as Vulnerable (VU) (MADV 2017). In Colombia, *A. griseimembra* is distributed in the inter-Andean river valleys of Magdalena and Cauca rivers, and in the Caribbean region including Serrania de San Lucas, Serrania del Perija, Montes de María and Sierra Nevada de Santa Marta (Link et al. 2019). It is important to highlight that the eastern of the Caldas department is an important area to allow the dispersion of *A. griseimembra* from south to north throughout the Magdalena Rver Valley.

CONCLUSIONS

After 21 years of not having reliable records of Jaguars in the Caldas department, this work renews the hope to conserve this iconic species in the territory and is perhaps the last opportunity to take conservation actions to prevent its local extinction in the department. Due to the high degree of isolation of "Ciénaga de la Tortuga", we believe that this remnant of forest must be prioritized and considered in the present and future conservation actions by the environmental authorities and the local, national, and international organizations dedicated to conservation of nature.

The remnant of tropical rainforest "Ciénaga de la Tortuga", apart from being inhabited by four threatened species of monkeys, also is inhabited by the Colombian Red Howler Monkey *Alouatta seniculus* (Image 6). Therefore, it is important to highlight that Ciénaga de la Tortuga is to date the only place in the Caldas department where it is possible to see five of the six species of

Image 6. (above) The Grey-handed Night Monkey *Aotus griseimembra* and (below) the Colombian Red Howler Monkey *Alouatta seniculus* recorded inside a tropical rainforest remnant known as "Ciénaga de la Tortuga" in the Magdalena river valley of the department of Caldas, Colombia. © Leonardo Mendieta-Giraldo.

monkeys currently recorded for the department (García-R. et al. 2018). The isolation of this forest patch and the high risk of disappearing in the short term, including these remnant populations of species at risk, make Ciénaga de la Tortuga a conservation priority for the department and even for the whole country; urgent actions are required and seem warranted to secure this remnant and ideally to reconnect it with other forest fragments in the region.

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Spanish Resumen: Durante décadas, el Valle Medio del Magdalena de Colombia ha sido escenario de un intenso conflicto social y civil, que ha resultado en una expansión sostenida y extensa de la frontera agrícola, dedicando la mayoría de las tierras a actividades de producción ganadera extensiva. Estas perturbaciones tan extensas han provocado la pérdida progresiva y el aislamiento de los bosques naturales de la región, amenazando gravemente la biodiversidad. Un grupo altamente susceptible a la extinción local en el Valle medio del Magdalena son los mamíferos grandes y medianos, pues suelen requerir grandes extensiones de hábitat con un buen grado de conectividad para poder dispersarse entre fragmentos. En este sentido, es especialmente importante identificar los últimos remanentes de hábitat que aún persisten en el Magdalena medio y que aún están ocupados por especies de mamíferos endémicos y amenazados. Por lo tanto, este trabajo confirma la presencia de Jaguar *Panthera onca* y cuatro monos amenazados, *Ateles hybridus* (En peligro crítico), *Saguinus leucopus* (En peligro), *Cebus versicolor* (En peligro) y *Aotus griseimembra* (Vulnerable) dentro de un remanente aislado de bosque lluvioso tropical llamado "Ciénaga de la Tortuga" en el Valle del Río Magdalena del departamento de Caldas. Luego de 21 años de no contar con registros confiables de Jaguares en el departamento de Caldas, este trabajo renueva la esperanza de conservar esta icónica especie en el territorio y es quizás la última oportunidad para tomar acciones de conservación para prevenir la total extinción local del Jaguar en el departamento. Este trabajo también representa los primeros registros confirmados de *C. versicolor* para el departamento de Caldas y los segundos registros conocidos de *P. onca* y *A. hybridus*. Los registros de *A. hybridus* también se consideran la localidad más austral de la especie.

Palabras clave: Grandes felinos, Capuchino *Cebus versicolor*, deforestación, especies amenazadas, especies endémicas, fragmentación, extinción local, Mono Nocturno *Aotus griseimembra*, Mono Araña *Ateles hybridus*, Tamarin *Saguinus leucopus*.

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Author contribution: Study design (LMG); Data collection (LMG); Data analysis (SEL, EGS, JFGM); Manuscript write up (SEL, EGS, JFGM).

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17875–17888
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6483.13.3.17875-17888
#6483 | Received 29 July 2020 | Final received 23 December 2020 | Finally accepted 19 February 2021
PLATINUM OPEN ACCESS

COMMUNICATION

First confirmed sightings of Blue Whales *Balaenoptera musculus* Linnaeus, 1758 (Mammalia: Cetartiodactyla: Balaenopteridae) in the Philippines since the 19th century

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Abstract: For over two centuries there were no records of Blue Whales *Balaenoptera musculus* in the Philippines. Whalers recorded Blue Whales in the Philippines in the 19th century, and the next confirmed sighting in the country was of a mother and calf in 2004. Since then 33 subsequent Blue Whale sightings of potentially one individual were recorded between 2004 and 2019, all within the central region of the Philippines around the Bohol Sea. This individual, recognized through photo-identification, was sighted on at least 13 occasions during eight different years: 2010, 2011, 2012, 2015, 2016, 2017, 2018, and 2019. The geographic location and timing of the sightings (January to July) suggest that Blue Whales in the Philippines may extend the outer range edge of the Indo-Australian population that migrate between western Australia, Indonesia, and East Timor. Blue Whale sightings in the Bohol Sea coincide with times of high ocean productivity, although further investigation is needed to determine if they are actually feeding in this region. Acoustic studies and photo-identification matching with other Blue Whale catalogues will clarify the stock identity of Blue Whales in the Philippines and their relation to the rest of the Blue Whale population, with implications for the conservation of this endangered species across multiple jurisdictions.

Keywords: Bohol Sea, photo-identification, survey.

Editor: Anonymity requested. **Date of publication:** 26 March 2021 (online & print)

Citation: Acebes, J.M.V., J.N. Silberg, T.J. Gardner, E.R. Sabater, A.J.C. Tiongson, P. Dumandan, D.M.M. Verdote, C.L. Emata, J. Utzurrum & A.A. Yaptinchay (2021). First confirmed sightings of Blue Whales *Balaenoptera musculus* Linnaeus, 1758 (Mammalia: Cetartiodactyla: Balaenopteridae) in the Philippines since the 19th century. *Journal of Threatened Taxa* 13(3): 17875–17888. https://doi.org/10.11609/jott.6483.13.3.17875-17888

Funding: The National Geographic Society, EC-54888C-18; Society for Conservation Biology; BALYENA.ORG; U.S. Fulbright Program; Ocean Park Conservation Foundation - Hong Kong, FH01_11/12, 2011/12 (JNS); Rufford Small Grants Foundation RSGF Grant Number: 53.02.10 and 21574-2; Ocean Park Conservation Foundation - Hong Kong, MM08.1011, 2010/11 (ERS); Condura Run for the Dolphins (2012); SU-IEMS.

Competing interests: The authors declare no competing interests.

For **Filipino abstract, Author details, Author contribution** and **Acknowledgements** see end of this article.

INTRODUCTION

Blue Whales *Balaenoptera musculus* Linnaeus, 1758 are currently classified as Endangered by the International Union for the Conservation of Nature (IUCN) (Cooke 2018), and sightings in the Philippines are rare. Although historical data suggests Blue Whales occurred in Philippine waters (Acebes 2014), their presence was not reported between the end of the 19th century (1870) and 2004. Stories from fishers from Bohol suggest sightings of mother-calf pairs in the early 1990s (Jo Marie V. Acebes pers. comm. 8.xi.2011). While a whale skull of unknown source labeled "Blue Whale" was once displayed on the grounds of a village town hall in Lila, Bohol, the evidence of Blue Whale occurrence in the 20th century remains anecdotal (Acebes 2013). The first confirmed documentation of a Blue Whale in the Philippines occurred when a mother and calf were filmed off Pamilacan Island in the Bohol Sea in February 2004 (Dolar & Sabater 2012; Acebes 2014). The animal was initially thought to be a Bryde's Whale *Balaenoptera edeni* Anderson, 1879, but was subsequently identified as a Blue Whale (Acebes 2006). Photographs of a baleen whale seen in the same area in May 2004 were also confirmed to be a Blue Whale (Sabater 2005). These sightings were brief and no detailed information on the animal and its behavior were recorded.

With such a gap in time between records, the subspecies and population of the Blue Whale seen in 2004 was unclear. There are four recognized subspecies of Blue Whale (Committee on Taxonomy 2019); however, many authorities do not recognize the northern Indian Ocean subspecies *Balaenoptera musculus indica* (Blyth, 1859) as separate from Pygmy Blue Whales *Balaenoptera musculus brevicauda* (Ichihara, 1966) because of a lack of morphological differences (Branch et al. 2007b; Branch & Mikhalev 2008; Jefferson et al. 2015). Antarctic Blue Whales (*Balaenoptera musculus intermedia* Burmeister, 1871) are restricted to Antarctic waters south of 60°S and are morphologically and genetically distinct from other subspecies (Rice 1998; Kato et al. 2002; Branch et al. 2007a,b; LeDuc et al. 2007; Branch & Mikhalev 2008; Branch et al. 2009). *Balaenoptera musculus musculus* (Linnaeus, 1758) are found only in the Northern Hemisphere and, while longer and heavier than *B.m. indica* and *B.m. brevicauda*, are still shorter and lighter than *B.m. intermedia* (Jefferson et al. 2015).

Populations of Blue Whales can also be separated acoustically into at least 10 distinct populations (Rankin et al. 2005; McDonald et al. 2006, 2009; Stafford et al. 2011; Širović et al. 2018). The Philippines lie on the edge of the North Indian, Southeast Indian, North Pacific, and Southern Ocean acoustically-recognized populations.

The central Indian Ocean population (*B.m. indica)*, is found in highest concentrations around Sri Lanka and appears to be resident in nature (de Vos et al. 2012, 2016), while at least some individuals from the Southeast Indian population (currently identified as *B.m. brevicauda)* undergo migrations from western Australia to Indonesia, arriving by June (Branch et al. 2007b; Double et al. 2014). North Pacific *B.m. musculus* are recognized as at least two acoustically separate populations, the eastern North Pacific population (ENP) and western North Pacific population (WNP), with almost none sighted south of northeastern Japan for decades (McDonald et al. 2006, 2009; Branch et al. 2019). The western North Pacific Blue Whales were historically hunted as far south as Taiwan (Tomilin 1957; Stafford et al. 2001; Wang et al. 2001), but were virtually extirpated from the southern part of their range, including southern Japan (National Marine Fisheries Service 1998; Clapham et al. 1999; Gilpatrick & Perryman 2008). Southern Ocean *B.m. intermedia* remain south of 52°S during the austral summer, but their acoustic song is heard throughout the Southern Hemisphere in the winter months (Stafford et al. 2004, 2011; Rankin et al. 2005; McDonald et al. 2006, 2009; Branch et al. 2007b; Samaran et al. 2013, 2019; Shabangu et al. 2019). The Philippines is geographically situated between the known ranges of *B.m. brevicauda*, *B.m. indica*, and *B.m. musculus* subspecies, but is closest to the Southeast Indian Ocean population of *B.m. brevicauda*. Since sub-specific taxonomy remains unresolved (Cooke 2018) (See Fig. 1), we consider all Blue Whale sightings here to be *B. musculus* sp.

We describe all documented encounters with Blue Whales in the Philippines since 2004. We investigate the distribution and ecology of Blue Whales in the Philippines by reviewing the timing and location of these sightings and examining the behavior of animals encountered, and photographically identifying the whales to initiate a photo-identification catalogue for the country.

Abbreviations: ENP—Eastern North Pacific | GPS—Geographic Positioning System | IUCN—International Union for the Conservation of Nature | LAMAVE—Large Marine Vertebrates Institute Philippines | PCBs—Polychlorinated Biphenyls | SHBWP—Southern Hemisphere Blue Whale Photo-ID | SLR—Single Lens Reflex | SU-IEMS—Silliman University - Institute of Environmental and Marine Sciences | SWIMS-HK—Swire Institute of Marine Science of the University of Hong Kong | WNP—Western North Pacific.

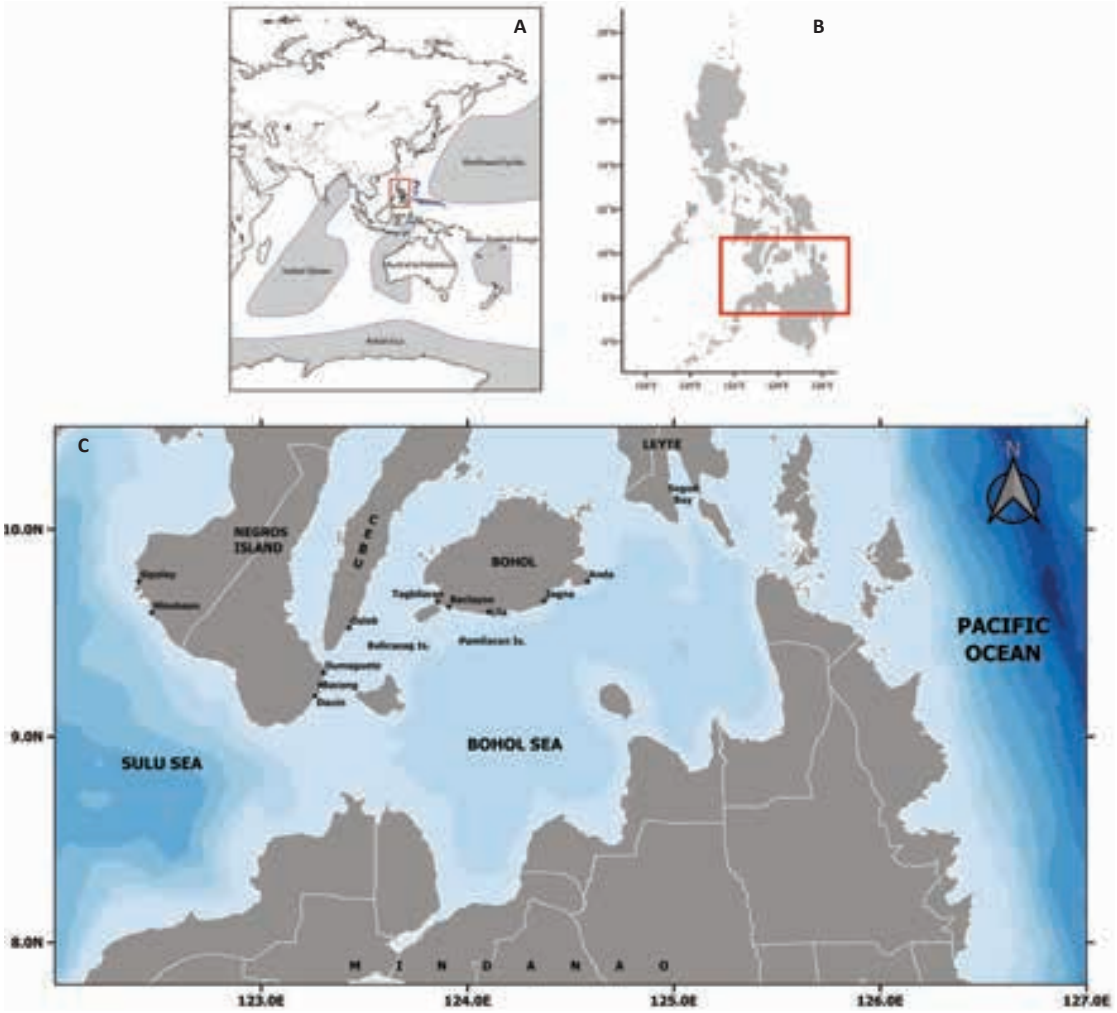

Figure 1. Known geographic ranges of blue whales in relation to the Philippines: A—shows the location of the Philippines in relation to the known geographic ranges of blue whale populations | B—shows the map of the Philippines and the location of the Bohol Sea | C—shows the Bohol Sea in the Central Visayas region of the Philippines.

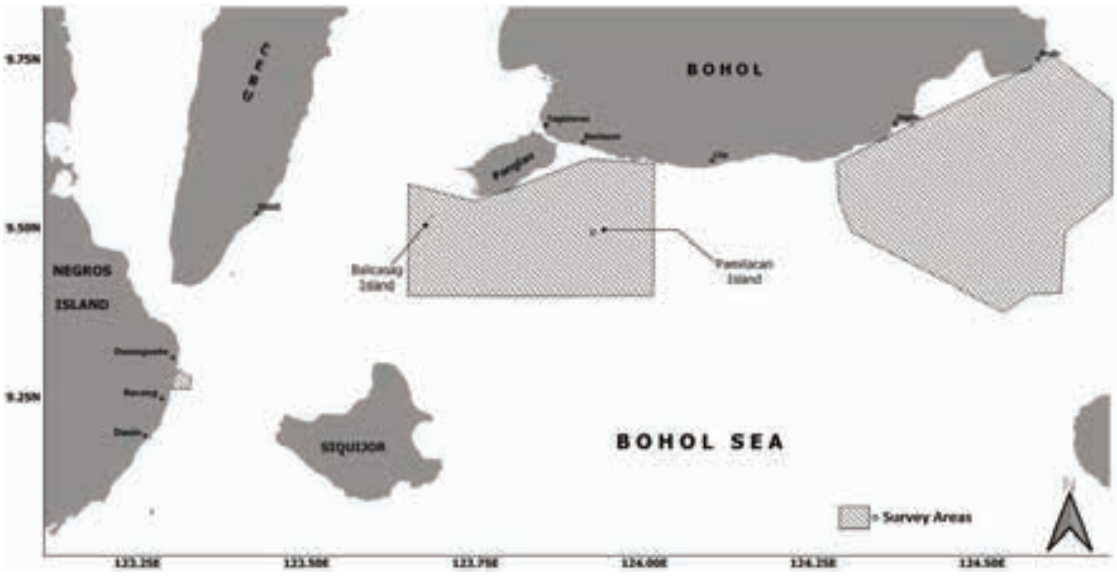

Figure 2. Study site in the Bohol Sea with areas surveyed marked with polygons with diagonal lines.

MATERIALS AND METHODS

Study site

The primary study site was the Bohol Sea, also known as the Mindanao Sea (Fig. 2). The Bohol Sea is located in the central Philippines (9˚N & 124˚E) and is surrounded by the island of Bohol in the north, southern Leyte in the east, and northwestern Mindanao in the south. It covers 29,000km² and measures 270km east to west (Indab & Suarez-Aspilla 2004; Green et al. 2004). Located in the centre of the Philippine archipelago, the Bohol Sea connects to the Sulu Sea to the west and to the Pacific Ocean in the east. Because the Bohol Sea has a relatively short continental shelf, there is considerable pelagic ocean habitat close to the shores of the surrounding islands — distinctive bathymetric conditions that contribute to deep water upwelling and associated high primary productivity (Cabrera et al. 2011; Gordon et al. 2011), and are similar to regions favored by Blue Whales off California and Australia. Cetaceans in the Bohol Sea are relatively understudied compared to cetaceans in other areas of the Philippines, owing to the sea's large area. Confirmed sightings of *B. musculus* sp. in the Philippines since 2004 have all been in the Bohol Sea region.

Sighting reports review

We collected and reviewed reports of sightings of Blue Whales and other large baleen whales in local news and social media, and examined photographs and videos to verify the species by looking for distinctive characteristics. Other photos and videos of large baleen whales submitted to the authors were included when quality was sufficient to verify that it was a Blue Whale. We counted separate encounters of the same individual whale on one day as a single sighting.

Blue Whales were morphologically distinguished from other baleen whales through several distinctive characteristics: 1) the "splash guard" or the prominent fleshy ridge anterior to the blowhole; 2) the large, broad, U-shaped head; 3) the relatively small dorsal fin positioned far back on the body; and 4) the mottled pigmentation in light and dark shades of gray found dorsoventrally along the body of the animal except the head and fluke (Sears 2002). Out at sea on a calm day from a distance, a Blue Whale projects a tall, dense, broad blow which can also be used to distinguish it from the Fin Whale *Balaenoptera physalus* Linnaeus, 1758.

Small vessel-based surveys

Small vessel surveys were conducted in the Bohol

Table 1. Survey effort of different research groups from 2010 to 2019.

Research Group	Survey period	No. of Days
LAMAVE	iii.2010	1
	iv.2010	2
	v.2010	8
	11.vi.2010	1
	iv.2011	4
	v.2011	3
	vi.2011	7
	iii.2012	4
	iv.2012	2
	v.2012	13
	vi.2012	2
	iv.2013	4
	v.2013	11
	vi.2013	6
	TOTAL	**68**
SU-IEMS	vi.2010	2
	x.2010	4
	xi.2010	10
	iv.2011	15
	v.2011	8
	x.2011	2
	iii.2012	2
	iv.2012	6
	v.2014	5
	vi.2014	4
	TOTAL	**58**
BALYENA.ORG	18–25.v.2015	9
	19–27.v.2016	9
	19–27.v.2017	9
	19 & 21.vii.2017	2
	26—29.i.2018	4
	23.v–1.vi.2018	10
	10–12.iii.2019	3
	16—18.iii.2019	3
	26—28.iii.2019	3
	15–17.iv.2019	3
	23–26.iv.2019	4
	21–27.v.2019	7
	22.vii.2019	1
	TOTAL	**67**
SWIMS-HKU	25.v.2016	1
	TOTAL	**1**

Sea between 2010 and 2019 by four different research groups (described further below, for a summary see Table 1 and Fig. 2). In all surveys, cetacean encounters were documented by recording the species, pod composition, number, and behaviour. We used a handheld Geographic Positioning System (GPS) to record the location of sightings. We photographed all cetacean species encountered, and estimated the sizes of animals using known boat length, when possible.

The Institute of Environmental & Marine Sciences of Silliman University (SU-IEMS) conducted systematic line-transect surveys using the distance sampling technique (Buckland et al. 2001), between June 2010 and June 2014 in the northwestern Bohol Sea using 20m long outrigger boats (See Table 1 and Fig. 2). Equal-distance zigzag design was followed. Transect legs were 20–25 km in length, 10km apart at the base, covering an area of 766km². This survey was strategically developed to investigate cetacean distribution and abundance in the study area over time.

The Large Marine Vertebrates Institute Philippines (LAMAVE) conducted non-systematic, non-random surveys in the northeastern Bohol Sea and the area around Pamilacan Island using 7–10 m long outrigger boats. The primary objective of these surveys was to photo-identify Melon-headed Whales *Peponocephala electra* (Gray, 1846), hence the search pattern was set to maximize these sightings by searching between three and 25km from shore across depths ranging between 200 and 2,000 m. In addition, if there were local reports of large whales in the area, a survey was conducted as soon as possible.

BALYENA.ORG conducted strip transect surveys in the northern Bohol Sea from Anda in the East to Valencia in the West, including the area around Pamilacan Island using an 18–20 m long outrigger boat from 2015 to 2019 (see Table 1 for details). The transect lines were set at 1km from the coastline, radiating five to 6km out and were approximately 1km apart. Opportunistic surveys were conducted in July 2017, January 2018, and March 2019 around Pamilacan Island when Blue Whale sightings were reported.

An opportunistic survey was conducted by a team from the Swire Institute of Marine Science of the University of Hong Kong (SWIMS-HKU) along the southern coast of Negros Oriental in May 2016 after receiving reports of a sighting of a Blue Whale in the area. An inflatable rubber boat about five to 7m long with a 25hp engine was used to survey along the coast about one to two kilometres from shore.

Photographic identification

We used 35mm digital single lens reflex (SLR) cameras with 70–400 mm zoom lenses. We photo-identified the animals using standard techniques used for Blue Whales (Sears 1990; Calambokidis & Barlow 2004; Gendron & De La Cruz 2012). We photographed both sides of the flank from a perpendicular angle, and included the dorsal fin as a point of reference. As much as possible, we photographed the entire flank of the animal in one sequence as the whale rounded out to dive. We also photographed the head and fluke. We used photographs of the fluke as part of the identification whenever possible. Photographs were considered good for photo-identification based on the sharpness of the image, the lighting and if the image was large enough for the markings to be clearly seen (Sears 1990). We compared good quality photographs taken of Blue Whales encountered with the BALYENA.ORG catalogue, and conducted an informal comparison with Geographe Bay and New Zealand photos included in the Southern Hemisphere Blue Whale Photo-ID (SHBWP) Catalogue (e.g., Galletti-Vernazzani et al. 2019), which included left-side comparisons with 74 images (Chandra Salgado-Kent pers. comm. 13.iv.2019).

RESULTS

Reported sightings in local news and social media

A total of 23 Blue Whale sightings were reported since 2004 based on reports in the local news and social media (Table 2). All reports were verified by examining the photographs or videos. Although all the photographs and videos examined were adequate for species identification, only one was suitable for photo-identification.

Ten sightings occurred in the area off Pamilacan Island, while three occurred off Panglao Island, both in the province of Bohol (Fig. 3). Two sightings were observed off the southern point of Sogod Bay in the province of Southern Leyte at the far eastern edge of the Bohol Sea. One sighting was from Oslob in southwestern Cebu, directly south-east of Bohol. Five sightings occurred off the coast of Dauin and Dumaguete in southwestern Negros Oriental, and an additional two sightings were reported from Sipalay and Hinoba-an along the southwestern shore of Negros Occidental. All sightings were of a solitary animal except for the first sighting in 2004, which was of a mom and calf. No detailed description of the behaviour was recorded because almost all sightings were made by tourists who

Table 2. Confirmed sightings of blue whales in the Philippines from 2004 to 2019.

Date sighted	Reported sightings	Location	Estimated size (m)	Group composition
ii.2004	Sports Unlimited (local TV crew)	Pamilacan Island	-	Mother and calf
1.v.2004	Pet Digdigan & Virginia Montgomery	Pamilacan Island	-	single
20.v.2008	Eulo Valeroso	east of Pamilacan Island	-	single
12.iii.2010	Louise Dixon	Two nautical miles from Napantao, east of Sogod Bay, So. Leyte	-	single
14.iii.2011	GMA Born-To-Be-Wild (local TV crew)	Pamilacan Island	25–30m	single
24.v.2015	Suzette Pepito	Between Panglao Island and Balicasag Island	-	single
iii.2016	Jojo Baritua	Pamilacan Island	-	single
3.iv.2016	-	Oslob, Cebu	-	single
13–14.iv.2016	Nemesia Pingkian	Pamilacan Island	-	single
28.iv.2016	Justin Jordan Reloj	Padre Burgos, So. Leyte	-	single
17.v.2016	Danny Ocampo	Canday-ong, Dumaguete, Negros Oriental	-	single
20.v.2016	Joseph Jasper Acay	Panglao Island	-	single
23.v.2016	Lyka Marie Abella	Dauin, Negros Oriental	-	single
24–26.v.2016	GB Aguilar, Harold Biglete, Judalyn Flores Partlow	San Miguel, Bacong-Dumaguete City, Negros Oriental	-	single
29.v.2016	-	Sipalay, Negros Occidental	-	single
4.vi.2016	-	Hinoba-an, Negros Occidental	-	single
18.vii.2017	Manong Sonny	off Pamilacan Island	-	single
11.viii.2017	Rico Ramos	5km off Dauin, Negros Oriental	-	single
1–5.iii.2018	Jojo Baritua	off Pamilacan Island	-	single
3.iii.2018	Jojo Baritua	Cervera shoal, west of Pamilacan	-	single
12–18.iii.2018	Jojo Baritua	off Pamilacan Island	-	single
22.iii.2018	Zita Lin	off southern coast of Panglao	-	single
10.iii.2019	Vanela Grace Torres	off Dauin, Negros Oriental	-	single
	Survey sightings			
11.vi.2010	LAMAVE	9.47835N & 123.94426E	22m	single
29.iii.2012	LAMAVE	Pamilacan Island	19m	single
25.v.2015	BALYENA.ORG	09.51238N & 124.11468E	22m	single
25.v.2016	SWIMS-HKU	09.26222N & 123.32779E	20–21m	single
19.vii.2017	BALYENA.ORG	9.53003N & 123.8391E	less than 30m	single
21.vii.2017	BALYENA.ORG	9.469N & 123.85447E	less than 30m	single
26.i.2018	BALYENA.ORG	9.516725N & 123.90106E	Under 30m	single
27.i.2018	BALYENA.ORG	9.47678N & 123.88336E	Under 30m	single
29.i.2018	BALYENA.ORG	9.54751N & 123.91459E	Under 30m	single
29.i.2018	BALYENA.ORG	9.5594N & 123.93287E	Under 30m	single
26.iii.2019	BALYENA.ORG	9.46154N & 123.87368E	19–20m	single

happened to be on a boat passing the area. According to the local TV crew that documented the encounter with a Blue Whale in March 2011, the whale excreted a reddish-brown liquid twice while they were following it. The whale was estimated to have a dive interval of 15 to 20 minutes.

The longest, almost continuous sighting of an individual Blue Whale in the Philippines was in 2016, over 19 days from May to June along the southern coasts of Negros Oriental and Occidental. Tracking the sighting locations within this period seems to indicate that the whale was moving northwest, exiting the Bohol Sea and

Figure 3. Point locations of blue whale sightings from surveys and sightings. Red circles are sightings from vessel surveys while green crosses are from reported sightings.

traveling towards the Sulu Sea, as it was last sighted off the southwestern coast of Negros Occidental.

Sightings from small vessel-based surveys

Eleven Blue Whale encounters were documented based on small vessel surveys between 2010 and 2019 (Table 2). All sightings occurred in the area off Pamilacan Island, Bohol (Fig. 3) except for the 25 May 2016 sighting from the coast of Dumaguete City in southern Negros Oriental.

LAMAVE conducted surveys in 2010, 2011, 2012, and 2013. In 2010, 12 survey days were conducted between March and June. In 2011, 14 survey days were conducted from April to June. In 2012, 21 survey days were conducted from March to June. In 2013, 21 survey days were conducted from April to June. During all surveys, a Blue Whale was encountered twice—June 2010 and March 2012 (Table 2).

SU-IEMS surveys were conducted in June 2010, October-November 2010, April-May 2011, October 2011, March-April 2012, and May-June 2014. The total effort was 58 survey days covering 766km² of the area. No Blue Whales were encountered in any of the surveys but other balaenopterids were seen.

The BALYENA.ORG surveys were conducted from 2015 to 2019 for a total of 67 combined dedicated strip-transect and opportunistic survey days. Dedicated strip-transect surveys during 61 days covered 1,191km² of area (Figure 2). A Blue Whale sighting was recorded on 25 May 2015 during the 2015 dedicated survey, but no Blue Whales were sighted during the subsequent 2016 to 2019 dedicated surveys (See Table 2). Following reported Blue Whale sightings off of Pamilacan Island, a Blue Whale was encountered on 19 and 21 July 2017; 26, 27, and 29 January 2018; and March 26, 2019 during opportunistic surveys. On 29 January 2018, a Blue Whale was encountered twice, in the morning and afternoon.

On 25 May 2016, a large whale sighting was reported off Dauin, Negros Oriental. A team from SWIMS-HKU headed southeast along the coast of Dumaguete City and was able to locate the animal about 2km from shore and confirmed the species as Blue Whale. The team followed it for one hour and 11 minutes as it moved up and down the coast off Bacong town and Dumaguete City before eventually losing the animal due to unfavorable conditions. The whale was sighted again several hours later as close as 900m from shore. The whale was observed milling.

All individuals fit the description of 'pygmy' Blue Whales by Kato et al. (2002) based on the body shape, coloration, dorsal hump, and blowhole morphology. The individual encountered in June 2010, May 2015, and May 2016 was estimated to be 20 to 22 m long, while the individual encountered in 2012 and 2019 was estimated to be 19 to 20 m. The difference in size estimation is most likely due to the subjectivity of observers.

All Blue Whales encountered during the surveys were solitary. The whale encountered on 29 March 2012 was

associated with Spinner Dolphins *Stenella longirostris*. At all encounters, except in May 2016, the whale appeared to be resting. When approached, the whale swam away or dove, resurfacing a hundred meters away or more from the research boat. In 2015, the whale's surface interval was brief. Two or so breathing bouts were observed, followed by a dive, and the whale would resurface 500m or more away from the boat after the completion of its dive. In 2018, surface intervals were for approximately one to five minutes, with about 10–15 breathing bouts, and the whale resurfaced 500 or more meters away after the completion of its dive. In 2019, the surface interval was longer at approximately nine to ten minutes, with about 10–14 breathing bouts.

Photographic identification

The photograph of the left flank of a Blue Whale taken by the host of the local TV show on 2011 was compared with the photographs of the Blue Whale encountered during the survey in 2010 and 2015, and was confirmed to be the same individual.

Photographs of the left and right side of the Blue Whale encountered in vessel-based surveys in 2010, 2012, 2015, 2016, 2017, 2018, and 2019 were taken. Based on comparison of the photographs of the left side of the Blue Whales encountered it was found that the same individual was photo-identified on 11 June 2010, 29 March 2012, 25 May 2015, 25 May 2016, and 21 July 2017 (Image 1). Closer examination of the photographs of the left side of the dorsal fin of the blue whale encountered in 2010, 2012, 2015, 2016, 2017, and 2019 revealed an identical semi-circular indentation, which further confirmed the identification (Image 2). A good photograph of the ventral side of the fluke of the Blue Whale encountered in May 2015, May 2016, January 2018, March 2018, and March 2019 was also taken. Examination of the fluke photos revealed identical notches on the left and right sides of the tip of the fluke of all whales photographed (Image 3). Results show that all 13 sightings of Blue Whales in eight different years were of the same individual.

DISCUSSION

Despite the efforts of four research groups with an accumulated effort of 194 days over 10 years between the months of January and July, and between October

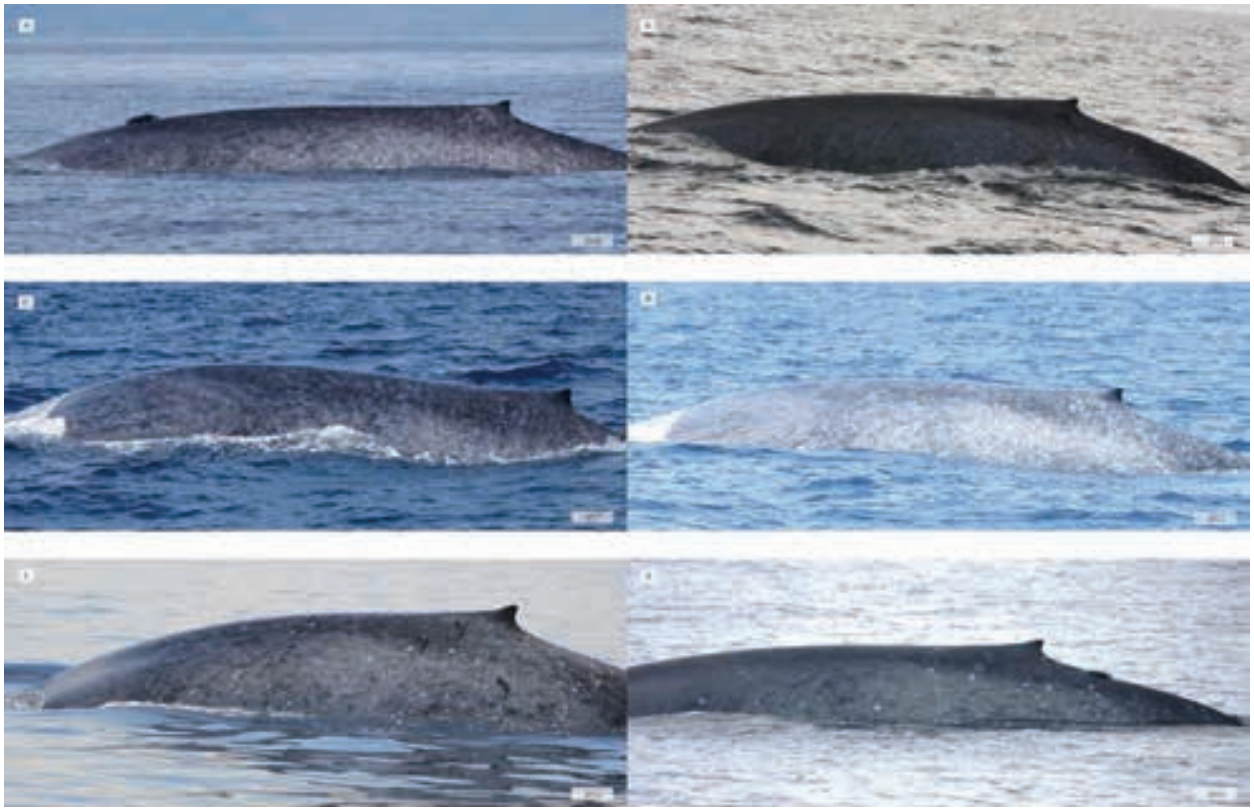

Image 1. Photographic identification of the blue whale sighted in A—2016 © Angelico Tiongson | B—2011 © Ferdinand Recio | C—2017 © Maita Verdote | D—2015 © Jom Acebes | E—2012 © Josh Silberg | F—2010 © Jom Acebes, showing similar pigmentation on the left flank.

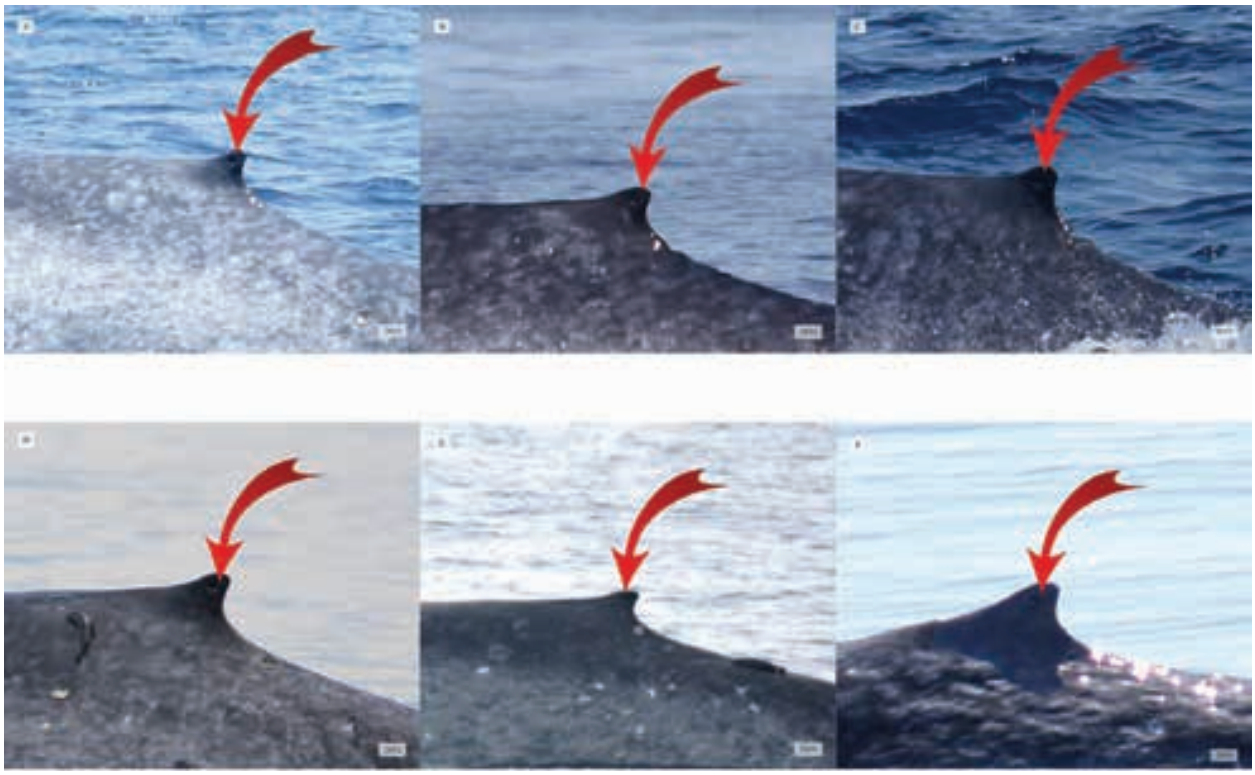

Image 2. Left side of the dorsal fin of the blue whale encountered in A—2015 © Jom Acebes | B—2016 © Angelico Tiongson | C—2017 © Maita Verdote | D—2012 © Josh Silberg | E—2010 © Jom Acebes | F—2019 © Angelico Tiongson, showing identical semi-circular indentation.

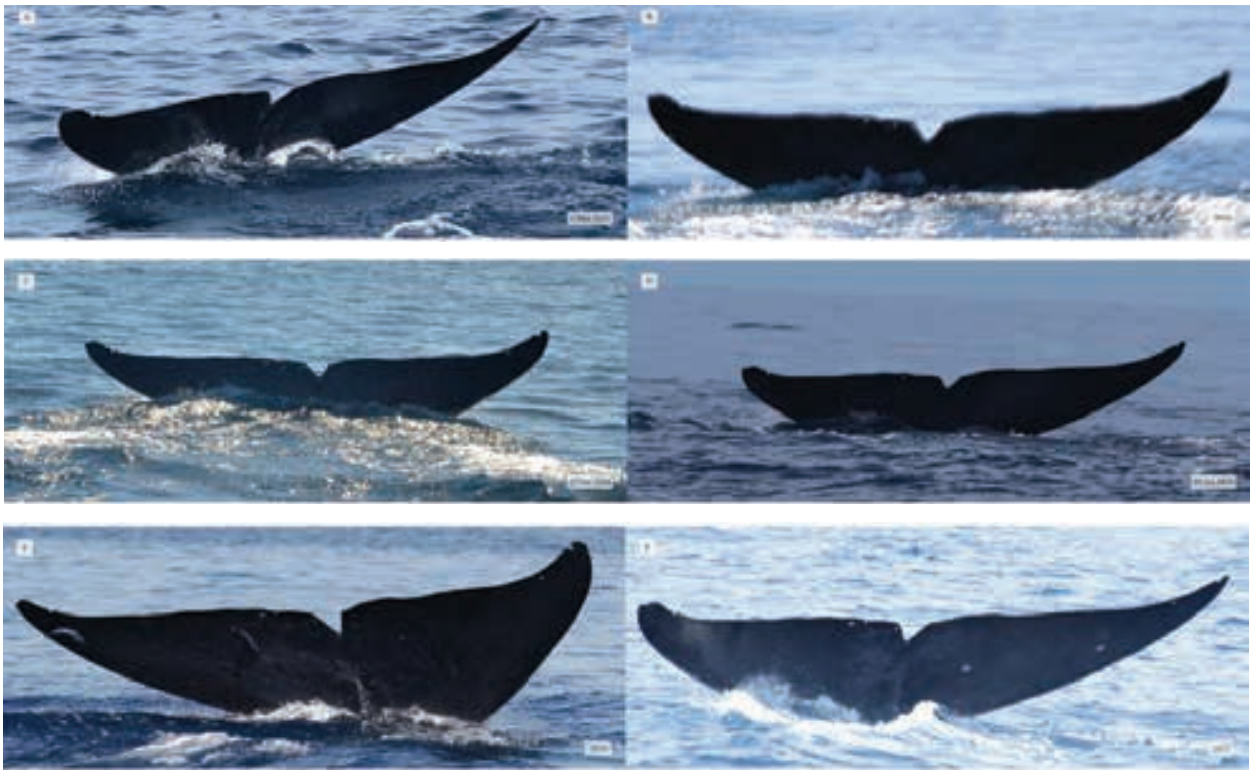

Image 3. Ventral side of the fluke of the blue whale encountered on A—3 March 2018 © Jojo Baritua | B—2019 © Angelico Tiongson | C—27 Jan. 2018 © Zerlina Leung | D—29 January 2018 © Kent Truog | E—2016 © Angelico Tiongson | F—2015 © Jom Acebes, showing identical nicks or notches.

and November, covering a total area of approximately 2,092km² of the northern Bohol Sea (Table 1 and Fig. 2), there was a paucity of Blue Whale encounters. This suggests that the species is not common in the region; however, given the size of the area of the Bohol Sea, the combined survey effort of these groups was probably not sufficient to cover the possible area of occurrence of the species. It must also be noted that most surveys were not conducted consistently during the same month within the same area each year, nor did they cover the entire month.

Although inconsistent, sightings of Blue Whales in the Bohol Sea are significant because they represent the only area in the Philippines that this Endangered species has been sighted and photo-documented. Sightings reported and recorded during the surveys were between the months of January and July, with most sightings having occurred in May. This coincides with local ecological knowledge about the seasonal presence of large marine vertebrates in the Bohol Sea. According to local fishers and residents, baleen whales come to the Bohol Sea between January and June with a peak from March to May (Acebes 2013).

It is possible that baleen whales come to the Bohol Sea to feed, as evidenced by their presence during the months of high productivity and observations of former whale hunters (Acebes 2013). Blue Whale feeding is often associated with coastal upwelling and other oceanographic features (Fiedler et al. 1998; Palacios 1999; Gill 2002; Best et al. 2003; Etnoyer et al. 2004, 2006; Croll & Marinovic 2005; Rennie et al. 2009). The Bohol Sea's connections with deep basins, the Pacific Ocean to the east and the Sulu Sea in the west, give it "unique circulation and physicochemical properties" (Cabrera et al. 2011). Furthermore, the water movements—sea surface currents, formation of eddies, and entrainments—cause upwelling and brings seasonal variations in productivity, food supply, and subsequently, fish abundance in the Bohol Sea (Cabrera et al. 2011; Gordon et al. 2011).

Some site fidelity exists, as evidenced by the re-sighting of an individual Blue Whale 13 times between 2010 and 2019. Only one mother-calf pair has been recorded in the Philippines (See Table 2). The relatively low frequency of sightings suggests the area is unlikely to be a prominent breeding ground similar to the situation in Chile (Hucke-Gaete et al. 2004). There are still very limited sightings data to give any idea on the movements or habitat-use of this Blue Whale in the Philippines.

The population identity of Philippine Blue Whales remains unclear. The estimated size of all of the encountered Blue Whales (≤ 22m) falls within the maximum length of *B.m. brevicauda* (24.2 m) (Ichihara 1966; Omura 1984). The Philippines may represent a northward extension of the Australia/Indonesia stock. This is highly likely as Blue Whales have been reported in south-east Asian waters in southern Indonesia between May and November (Kahn et al. 2000; Branch et al. 2007b; Kahn 2007) and off Timor-Leste between September and November (Dethmers et al. 2012). In 2006, one animal stranded in Sabah, Malaysia (Ponnampalam 2012) suggesting that the stock range may extend farther north. Recent satellite telemetry studies indicate that Pygmy Blue Whales feeding off western Australia migrate north to Indonesia, reaching the northern end of their migration by June (Double et al. 2014). It also showed that the Banda and Molucca Seas are potential breeding grounds based on the timing of the movement of tagged Pygmy Blue Whales (Double et al. 2014).

Other populations of Blue Whales inhabit the Indian Ocean (Branch et al. 2007b). Acoustical comparisons suggest that at least some of the Indian Ocean populations migrate between Madagascar and Diego Garcia and between the Maldives/Sri Lanka and Diego Garcia (Branch et al. 2007b). This acoustical population has also been recorded off Crozet Island to the south (Samaran et al. 2010) and off Angola in southwestern Africa (Cerchio et al. 2010; Figueiredo & Weir 2014). The 2006 stranding in Sabah, Malaysia (Ponnampalam 2012) could also have belonged to this population. While north-south migration has been noted within the Indian Ocean, no eastward migration of Blue Whales has been recorded in the Andaman Sea, Malacca Strait, or Gulf of Thailand.

Philippine Blue Whales may also belong to the mostly extirpated western North Pacific stock owing to its proximity to Taiwan. The most recent record of a Blue Whale in this region is a 20 m long carcass found on the beach of Taitung County, Taiwan on 25 January 2020 (NAMR 2020). There are no other records of sightings of Blue Whales between Taiwan and the central Philippines. Blue Whale calls from the western North Pacific are different than those from the eastern North Pacific (Stafford et al. 2001; Monnahan et al. 2014) with calls recorded least often in winter and spring, suggesting a possible migration. Both vocalization types were recorded in the central Pacific (Stafford et al. 2001) and have been noted from Midway Island (Northrup et al. 1971).

It is important to gather additional data on the species, given the existing threats to cetaceans in the region such

as the risk of entanglement with fishing gear and ship strike (Laist et al. 2001; NOAA 2009; de Vos et al. 2016), especially around the busy shipping lanes in the vicinity of Dumaguete City and Cebu, the third largest city in the Philippines. The Bohol Sea is one of the main fishing grounds in the Central Visayas region (Green et al. 2004) where commercial and municipal fishing vessels may potentially pose risk of gear entanglement to whales. Overfishing of high trophic level species in the Bohol Sea (Lavides et al. 2010) may have unknown impacts to large whales in the region by reducing predation on plankton-feeding fish leading to increased competition for prey resources. Other unassessed anthropogenic threats in the area include noise associated with shipping and seismic exploration (National Marine Fisheries Service 1998; Di Iorio & Clark 2010; Melcón et al. 2012), pollutants such as polychlorinated biphenyls (PCBs) and organochlorines (Metcalfe et al. 2004), and unregulated dolphin and whale watching operations.

Blue Whales have been seen in the Philippines for the first-time since the end of the 19th century. The re-sighting of a single animal on 13 occasions across eight years suggests potential site fidelity for at least certain individuals. Acoustic studies and increased photo-identification survey effort with matching with other Blue Whale catalogues will help clarify the stock identity of Blue Whales in the Philippines and their relation to the rest of the Blue Whale population. The timing of Blue Whale sightings in the Bohol Sea coincides with sightings of the Indo-Australian Blue Whale population and may represent an extension of the outer edge of this population's range.

Longer, dedicated surveys must be conducted in the areas in the Bohol Sea where these sightings occurred to determine the species' habitat-use and distribution. Increased survey effort all along the northern Bohol Sea and perhaps around the eastern and western straits will help determine the regularity of occurrence of the species in the region. Although preliminary data indicate that occurrence of the Blue Whale coincides with the areas and season of high productivity in the Bohol Sea, further investigation is needed to validate that whales are feeding in these waters.

The confirmation of the presence of Blue Whales in the Philippines contributes to our knowledge on the ecology and distribution of this endangered species. It further highlights the high marine biodiversity of the southeastern Asian seas region and the Coral Triangle and the need for further research and conservation in the region.

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Filipino abstract: Mahigit na dalawang siglo na walang naitala na blue whales *Balaenoptera musculus* sa Pilipinas. Ang mga blue whales ay naitala ng mga mananagat na nanghuhuli ng balyena noong ikalabinsiyam na siglo, at ang sumunod na pagkakita nito dito sa bansa ay ang mag-inang balyena noong 2004. Simula noon, 33 na pagkakita ng blue whales na maaaring isang indibidwal na balyena ang naitala sa pagitan ng 2004 at 2019, lahat sa loob ng Bohol Sea sa gitnang bahagi ng Pilipinas. Ang indibidwal na ito na nakilala sa pamamagitan ng photo-identification, ay nakita ng 13 na pagkakataon sa loob ng walong magkakaibang taon: 2010, 2011, 2012, 2015, 2016, 2017, 2018, at 2019. Ang lugar at panahon ng pagkakakita (Enero hanggang Hulyo) ay nagpapahiwatig na ang blue whales sa Pilipinas ay maaaring magpapalawak ng pinakadulo na paninirahan ng Indo-Australian na populasyon ng blue whales na lumilipat sa pagitan ng western Australia, Indonesia, at East Timor. Ang pagkakakita ng blue whale sa Bohol Sea ay sumasabay sa panahon ng mataas na produksyon ng dagat subalit kinakailangan pa ng masinsin na pag-aaral para malaman kung ang mga balyenang ito ay tiyak na nanginginain sa rehiyon na ito. Mga pag-aaral gamit ang acoustic at photo-identification na paraan na magpapakita ng pagkakapareho sa ibang mga blue whale catalogue ang makakapagbigay linaw sa stock identity ng mga blue whale sa Pilipinas at ang kanilang relasyon sa iba pang populasyon ng blue whales, na may implikasyon rin sa pangangalaga ng endangered species na ito sa ibayo ng maraming hurisdiksyon.

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Author contribution: JMVA analysed the identification photos, organized, participated in and took photographs for the boat-based surveys for BALYENA.ORG, collated the reported and survey sightings information and was a major contributor in writing and revising the manuscript. JNS participated in and took photos for the LAMAVE surveys and was a major contributor in writing the manuscript. TJG participated in the 2018 and 2019 surveys for BALYENA.ORG and was a major contributor in revising the manuscript. ERS organized, participated in and took photographs for the SU-IEMS surveys; made the maps for the manuscript and contributed in revising the manuscript. AJCT organized, participated in and took photographs for the SWIMS-HK survey. He also participated in and took photographs for the BALYENA.ORG 2019 survey and contributed in revising the manuscript. PD organized and participated in the BALYENA.ORG 2017 survey. DMMV helped organize, participated in and took photographs for the BALYENA.ORG 2017 survey. CLE helped organize and participated in the LAMAVE 2010 survey and the SU-IEMS surveys. JU participated in and took photographs for the BALYENA.ORG 2019 survey and the SU-IEMS surveys. AAY helped collect reported sightings information from social media.

Acknowledgements: The National Geographic Society funded the 2019 project: "In search of the lone Blue Whale in the Bohol Sea, Philippines." Research funding for the 2015, 2016, 2017, 2018, and 2019 BALYENA.ORG surveys was from contributions from volunteers – Raphael Almendral, Carlo Roberto Felix, Lorraine Lao, Sharon Lu, Marielle Panganiban, Michelle Relojas, Pierre Palallos, Luis Benjamin Jurado, Serena Lagorio, Alieth Bontuyan, Monika Jukubiak, Marcin Skowroński, Matt Tacatani, Fiona Angana, Mariele Gepte, Julie Ann Butron, Vina Angelica Perducho, Maita Beringuel, Kent Truog, Reina Castillo, Ivy Pangilinan, Anna Bianca Barrameda, Elaine Tacubanza, Maude Lachaine, Paul Soliman, Pia Ronquillo, Aaron Roa, Cedric Valere, Roleen Sevillena, Rick Dane Gomez, Dindo Karl Mari Malonzo, and Paulina Ocampo. We also thank BALYENA.ORG researchers Jesse Acebes, Zerlina Leung, Julia Motoomull, Takeya Sakamoto, Elson Aca, Jerome Hulin, and Mark de la Paz. Thanks to the Society for Conservation Biology Marine Section Conservation Research Small Grants Program for providing funding for BALYENA.ORG's 2017 survey. LAMAVE research was supported through a grant from Ocean Park Conservation Foundation – Hong Kong (J.S., A.P., K.P., FH01_11/12, 2011/12). We would like to thank Alessandro Ponzo of LAMAVE and their volunteers: Kristina Pahang, Dominic Clarke, Valeria Senigaglia, Caitlin Birdsall, Katie Hughes, Julissah Evangelio, and Gary Haskins. This research was also supported by the Rufford Small Grants Foundation (2010), Ocean Park Conservation Foundation – Hong Kong (OPCF-HK) (2010-2011), Condura Run for the Dolphins (2012), and SU-IEMS through E.R.S. The following are acknowledged for their support and assistance: The Swire Institute of Marine Science (SWIMS) at the University of Hong Kong, Institute of Environmental and Marine Sciences (IEMS) at Silliman University, Janet Estacion, Leszek Karczmarski, Dioscoro Inocencio, Ramon Raymundo, and Hans Seiter. The Dumaguete survey was conducted from internal funding of SWIMS-HKU to the Cetacean Ecology Lab. We thank the Local Government Units of Jagna, Baclayon, Panglao and Lila in Bohol. Support for the work of J.M.V.A. was provided by the Asia Research Centre – Murdoch University in Western Australia, BALYENA.ORG and the National Museum of the Philippines. Support for the work of T.J.G. was provided by the U.S. Fulbright Program and BALYENA.ORG. We are grateful to Dr. Chandra Salgado- Kent for her time and effort in making an informal comparison of our photo with the SHBW Catalogue. We thank Serhii Dashko for helping with our figures. Thanks to Joselino Baritua of Pamilacan Island Dolphin and Whale Watching Tours. We also thank Bill Perrin, Louella Dolar, Lory Tan, Pet Digdigan, Virginia Montgomery, Shelby Guigerre, Ferdinand Recio, GMA's Born-To-Be-Wild crew, Mr. Eulo Valeroso, Louise Dixon, Saturnina Quilas, Zita Lin, the Sports Unlimited TV crew, Suzette Pepito, Nemesia Pingkian, Justin Jordan Reloj, Danny Ocampo, Joseph Jasper Acay, Lyka Marie Abella, GB Aguilar, Harold Biglete, Judalyn Flores Partlow, Rico Ramos, Eric Rosenblad, Aissa Domingo, Manong Sany Baugbog, Jefrey Enas, Manong Roel, and Manong Neil; the Department of Agriculture - Bureau of Fisheries and Aquatic Resources.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17889–17894
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.5682.13.3.17889-17894
#5682 | Received 05 January 2020 | Final received 18 March 2021 | Finally accepted 19 March 2021
PLATINUM OPEN ACCESS

COMMUNICATION

Parasitic infection in captive wild mammals and birds in Bangabandhu Sheikh Mujib Safari Park, Cox's Bazar, Bangladesh

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Abstract: We investigated the infection rate of gastrointestinal (GI) parasite eggs and premature stages from different wild animals and birds in Bangabandhu Sheikh Mujib Safari Park, Dulahazra, Cox's Bazar. A total of 56 fecal samples were collected from 24 species during July to November 2012 using modified Stoll's ova dilution technique. Coprology analysis revealed that the overall rate of parasitic infection was 78.6%, of which 51.8% were helminths and 35.7% protozoa. The identified parasites were *Paramphistomum* spp. (7.1%), *Fasciola* spp. (5.4%), strongyles (26.8%), *Ascaris* spp. (3.6%), *Strongyloides* spp. (7.1%), *Dictyocaulus* spp. (5.4%), *Trichuris* spp. (3.6%), *Capillaria* spp. (5.4%), *Heterakis* spp. (3.6%), and *Balantidium coli* (35.7%). Mixed infection (21.4%) was observed in nine animals, including co-infection with *Balantidium coli* and strongyles in Tiger *Panthera tigris*, Sambar Deer *Rusa unicolor* and Pig-tailed Macaque *Macaca nemestrina*, *Strongyloides* spp., *Trichuris* spp. and larvae of *Dictyocaulus* spp. in Capped Langur *Trachypithecus pileatus*, *Balantidium coli* and *Capillaria* spp. in Clouded Leopard *Neofelis nebulosa*, *Fasciola* spp. and *Balantidium coli* in Spotted Deer *Axis axis*, *Ascaris* spp. and strongyles in African Elephant *Loxodonta africana*, *Strongyloides* spp. and *Heterakis* spp. in Peafowl *Pavo cristatus* and *Heterakis* spp. and strongyles co-infection in Great Pied Hornbill *Buceros bicornis*. It is concluded that GI parasites were prevalent in this safari park. Further epidemiological investigation is necessary for controlling parasitic infection.

Keywords: *Ascaris*, *Balantidium coli*, *Capillaria*, *Dictyocaulus*, *Fasciola*, GI parasites, *Heterakis*, infections, *Paramphistomum*, strongyles, *Strongyloides*, *Trichuris*.

Editor: Priya J.Gawande, Nagpur Veterinary College, Nagpur, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Hossain, M.N., A.R. Dey, N. Begum & T. Farjana (2021). Parasitic infection in captive wild mammals and birds in Bangabandhu Sheikh Mujib Safari Park, Cox's Bazar, Bangladesh. *Journal of Threatened Taxa* 13(3): 17889–17894. https://doi.org/10.11609/jott.5682.13.3.1788-17894

Funding: National Science and Technology (NST) of Bangladesh.

Competing interests: The authors declare no competing interests.

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Author contribution: ARD and NB conceptualized and designed the study. MNH collected samples. MNH and ARD identified parasites and analyzed the data. MNH, TF and ARD drafted the paper and made final revisions. NB and TF made critical revision of the manuscript. All the authors read the final version of the manuscript and approved it.

Acknowledgements: The authors acknowledge National Science and Technology (NST) of Bangladesh for granting the research fund. Sincere thanks to the authority of Bangabandhu Sheikh Mujib Safari Park for sample collection.

INTRODUCTION

Conservation of wildlife in many parts of the world is associated with zoological gardens (Parsani et al. 2001a). Zoo populations are unique and important sources for studying wildlife and their habitats, and to preserve endangered species through captive breeding and reintroduction programs (Schulte-Hostedde & Mastromonaco 2015). Parasitic diseases constitute a major problem for these animals while in captivity (Rao & Acharjyo 1984). In nature, practically no animal is free from parasitic infection, but they often develop resistance from low grade infections. Captive animals are vulnerable to GI parasites, which often cause severe illness or death. Common GI parasites of captive birds and mammals include nematodes, trematodes, cestodes and protozoa. It is possible to eliminate these parasites by giving proper attention to feeding, water and maintenance of hygiene, husbandry practices, disease prophylaxis and treatment in captivity. Usually, captive animals do not show alarming signs of parasitism if regular deworming practices are carried out (Parsani et al. 2001a).

The study of wildlife while in captivity has contributed greatly to our current biological knowledge. Zoos, wildlife breeding centers and research institutions are playing a vital role in this respect. Investigations on endoparasitic fauna are important for the study of their prevalence and geographical distribution (Zasityte & Grikienciene 2002). In Bangladesh, very few zoological gardens, safari parks and eco parks have been established which act as an important source of recreation for people of all ages. Among them, safari park is the wildlife park where visitors can observe freely roaming animals from protected vehicles (Chipperfield 1975). There have been few comprehensive studies on the prevalence of intestinal parasites in animals in zoological gardens of Bangladesh (Raja et al. 2014). The present study aimed to identify GI parasites and their present status in birds and mammals of Bangabandhu Sheikh Mujib Safari Park.

MATERIALS AND METHODS

Study area

This study was conducted at Bangabandhu Sheikh Mujib Safari Park, Dulahazra, Cox's Bazar, Bangladesh. The samples were examined in the laboratory, Department of Parasitology, Bangladesh Agricultural University, Mymensingh.

Study period

The study was conducted from July to November 2012.

Selection of animals

A total of 56 samples were collected from species including: Tiger *Panthera tigris* (4), Lion *Panthera leo* (4), Asiatic Black Bear *Ursus thibetanus* (4), Clouded Leopard *Neofelis nebulosa* (3), Black Fox *Vulpes vulpes* (1), Hog Deer *Axis porcinus* (4), Sambar *Rusa unicolor* (4), Spotted Deer *Axis axis* (4), Hippopotamus *Hippopotamus amphibious* (2), African Elephant *Loxodonta africana* (3), Wildebeest *Connochaetes taurinus* (4), Gayal *Bos frontalis* (2), Langur *Semnopithecus* sp. (2), Capped Langur *Trachypithecus pileatus* (3), Monkey *Macaca fascicularis* (2), Hoolock Gibbon *Hoolock hoolock* (2), Pig-tailed Macaque *Macaca nemestrina* (1), Emu *Dromaius novaehollandiae* (1), Peafowl *Pavo cristatus* (2), Guinea Fowl *Numida meleagris* (1), Great Pied Hornbill *Buceros bicornis* (1), Indian Pond Heron *Ardeola grayii* (1), and Vulture *Aegypius monachus* (1).

Collection and preservation of samples

Fecal samples were collected with the help of animal caretakers in the early morning from the floor to prevent contamination. Each sample was placed in a polythene bag containing 10% formalin. The opening edge of the bag was tightly closed and samples were labeled according to species with a marker.

Coprological examination

All samples were examined at the laboratory, Department of Parasitology, Bangladesh Agricultural University, Mymensingh. The samples were processed for microscopic examination. The ova/ cysts/ larvae of different parasites were identified according to Stoll's ova dilution technique to determine eggs per gram (EPG) or cyst per gram (CPG) of feces as described by Soulsby (1982).

Micrometry of ova and cyst

The sizes (length by width) in µm of ova, cysts and larvae of identified parasites were measured (Cable 1965).

RESULTS

Overall infection rate of GI parasites in animals

The overall rate of parasitic infection was 78.6% (44), where helminths and protozoan infection were 51.8%

(29) and 35.7% (20), respectively (Table 1). Identified parasites included protozoa *Balantidium coli* (35.7%); nematodes strongyles (26.8%), *Ascaris* spp. (3.6%), *Dictyocaulus* spp. (5.4%), *Strongyloides* spp. (7.1%), *Trichuris* sp. (3.6%), *Capillaria* spp. (5.4%), and *Heterakis* spp. (3.6%); and trematode *Fasciola* spp. (5.4%) and *Paramphistomum* spp. (7.1%) (Table 2). Results indicated that helminth infection were more common than protozoan infection.

Infection rate of mixed infection in animals

Mixed infection (21.4%) was observed in nine animals: Tiger, Sambar Deer and Pig-tailed Macaque (*Balantidium coli* and strongyles), Capped Langur (*Strongyloides* spp., *Trichuris* spp. and larvae of *Dictyocaulus* spp.; *Strongyloides* spp., *Trichuris* spp. and larvae of *Dictyocaulus* spp.), Clouded Leopard (*Balantidium coli* and *Capillaria* spp.), Spotted Deer (*Fasciola* spp. and *Balantidium coli*), Elephant (*Ascaris* spp. and larvae of strongyles), Peafowl (*Strongyloides* spp. and *Heterakis* spp.), Great Pied Hornbill (*Heterakis* spp. and strongyles) (Table 3).

Infection rate of GI parasites in carnivores

Among carnivores, 68.8% (11/16) animals were positive for GI parasites, of which 62.5% (10/16) were found positive for protozoa and 18.8% (3/16) samples were positive for helminthes. The detected parasites of carnivores included strongyles (12.5%), *Capillaria* spp. (6.3%) and *Balantidium coli* (62.5%). No parasite was found in Black Fox.

Infection rate of GI parasite in herbivores

Among herbivores, 100% animals were positive for GI parasites. Among them, 30.4% and 78.3% samples were found positive for protozoa and helminthes, respectively. The isolated parasites were *Fasciola* spp. (13.0%), *Paramphistomum* spp. (17.4%), strongyles (43.5%), *Balantidium coli* (30.4%), *Ascaris* spp. (8.7%), and *Capillaria* spp. (4.4%).

Table 1. Infection rate of GI parasites in different animals at Bangabandhu Sheikh Mujib Safari Park.

Type of animal	No. of sample examined	Protozoa infected (%)	Helminth infected (%)	Mixed infected (%)	Total infected* (%)
Carnivores	16	10 (62.5)	3 (18.8)	2 (12.5)	11(68.8)
Herbivores	23	7 (30.4)	18 (78.3)	4 (17.4)	23 (100)
Primates	10	3 (30.0)	5 (50.0)	4 (40.0)	7 (70.0)
Birds	7	0 (0.0)	3 (42.9)	2 (28.6)	3 (42.9)
Total	**56**	**20 (35.7)**	**29 (51.8)**	**12 (21.4)**	**44 (78.6)**

* Total no. of animals/ birds affected is less than the summation of individual infection because same animal/ bird was infected with more than one type of gastro-intestinal parasites

Table 2. Infection rate of GI parasites in different animals in Bangabandhu Sheikh Mujib Safari Park.

Types of parasites	Name of the parasites	No. of case	Infection rate (%)	Intensity of infection (EPG/ CPG)
Protozoa	*Balantidium coli*	20	35.7	100–500
Trematode	*Paramphistomum* spp.	04	7.1	100–300
	Fasciola spp.	03	5.4	100–200
Nematode	strongyles	15	26.8	100–1200
	Ascaris spp.	02	3.6	200–400
	Strongyloides spp.	04	7.1	100–1200
	Dictyocaulus spp.	03	5.5	600–700
	Trichuris spp.	02	3.6	300
	Capillaria spp.	03	5.4	100–700
	Heterakis spp.	02	3.6	100–200

Table 3. Mixed infection in different animals in Bangabandhu Sheikh Mujib Safari Park.

Name of animals	Name of parasites	No. of case
Tiger, Sambar Deer and Pig-tailed Macaque	*Balantidium coli* and strongyles	3
Capped Langur	*Strongyloides* spp., *Trichuris* spp. and larvae of *Dictyocaulus* spp.	2
	Strongyloides spp., and larvae of *Dictyocaulus* spp.	1
Clouded Leopard	*Balantidium coli* and *Capillaria* spp.	1
Spotted Deer	*Fasciola* spp. and *Balantidium coli*	1
Elephant	*Ascaris* spp. and strongyles	2
Peafowl	*Strongyloides* spp. and *Heterakis* spp.	1
Great Pied Hornbill	*Heterakis* spp. and strongyles	1

Table 4. Micrometry of egg/ cyst of different parasites.

Name of parasites	Size in µm
Balantidium coli	50 x 70
Paramphistomum spp.	160 x 90
Fasciola spp.	87 x 43.5
strongyles	72.5 x 43.5
Strongyloides spp.	58 x 29
Ascaris spp.	70 x 50
Capillaria spp.	45 x 25
Heterakis spp.	70 x 45
Trichuris spp.	79 x 36

Infection rate of GI parasite in non-human primates

Among primates, 70.0% animals were positive for GI parasites of which 30.0% and 50.0% samples were found positive for protozoa and helminthes, respectively. The detected parasites were *Strongyloides* spp. (30.0%), *Dictyocaulus* spp. (30.0%) and *Trichuris* spp. (20.0%), strongyles (20.0%), and *Balantidium coli* (30.0%).

Infection rate of GI parasite in birds

Among birds, 42.6% samples were positive for GI parasites. No samples were found positive for protozoa. The identified parasites were *Strongyloides* spp. (14.3%), *Heterakis* spp. (28.6%), *Capillaria* spp. (14.3%) and strongyles (14.3%).

Intensity of infection of GI parasites in different animals

In the present study, intensity of different parasites in different animals was also measured. The mean EPG/ CPG were calculated. The highest CPG (cyst per gram) was found in Pig-tailed Macaque for *Balantidium coli* as 500. The highest EPG (egg per gram) was found in Capped Langur for *Strongyloides* spp. (1200).

Micrometry of egg/cyst of different GI parasites in different animals

The sizes (length by width) in µm of egg/cyst of different GI parasites were measured in the present study (Table 4).

DISCUSSION

The objective of zoological gardens is to protect endangered animal species and to evaluate needs for protecting biodiversity. It helps to gain an accurate and updated knowledge of different diseases that affect wild and exotic animals when in captivity (Mitchell et al. 2009). In case of parasitic infection, animal keepers and visitors play an important role of mechanical vector of parasites and improper feeding systems can enhance the parasitic infection (Nasiri & Jameie 2019).

Overall 78.6% animals were found to be infected with GI parasites, which was close to the previous finding of Raja et al. (2014) at Dhaka Zoo in Bangladesh (78.7%) and slightly higher than the earlier reports of Opara et al. (2010) and Corden et al. (2008) in Nigeria (76.6%) and Spain (72.5%), respectively. The variation may be due to climatic condition, husbandry practice and feeding management of the study area. Environmental contamination could be through contaminated water or fodder, and even zoo workers have also been reported to play a role in transmission by acting as vectors and transmitting parasites through their shoes, clothes, hands, food, or with working tools (Adetunji 2014; Otegbade & Morenikeji 2014).

The infection rate of helminths infection (51.8%) was found higher than protozoan infection (35.7%). This is similar with the report of Parsani et al. (2001a) who revealed that 57.1% animals were positive for helminths infection and 18.8% for protozoa in Rajkot Municipal Corporation Zoo. The present study also confirms the report of Varadharajan & Kandasamy (2000) who recorded that 58.0% animals were positive for helminths infections and 6.0% were positive for protozoan infections. In this study, nematode and protozoan infection were commonly found due to its direct life cycle involving no intermediate host and transmitted by oro-fecal route through contaminated feed, water, and soil and have the potential to accumulate in a captive environment. A few trematode infections and no

cestode infection was recorded because of their indirect life cycle (Parsani et al. 2001b). In this park, animals and birds are reared in protective enclosure giving less chance of accessibility to the intermediate hosts of trematodes and cestodes.

In the present study, mixed infection observed in different animals and birds. The mixed infection in deer was recorded by Kanungo et al. (2010) in majority of the deer. Mutani et al. (2003) reported that 58.5% monkeys were infected with at least three parasite species and only 34.0% with one and two parasite species. This suggests that there is a fairly high rate of transmission of the parasites observed between individuals either because of the monkeys' gregarious nature or because of suitable environmental conditions (Mutani et al. 2003). The finding of mixed infection in this study might be due to presence of all aged animals in the same cages, feeding management and improper disposal of feces.

In this study, it is indicated that 68.8% carnivores were positive for GI infection. This finding is lower than the report of Muller-Graf (1995) and Lim et al. (2008) who reported that the prevalence was 97.3% and 89.3%, respectively. The differences may be due the subspecies of tigers in this study which are different from the previous. Also the geographical factors and environmental factors are responsible for this variation.

In this study, 100% herbivores were positive for GI parasites. This finding is absolutely higher than the all previous findings. Wahed (2004) reported that 44.4% herbivores were positive with GI parasites. The high prevalence of *Fasciola* sp. (13.5%) and *Strongyloides* spp. (11.5%) in deer was recorded by Mandalet al. (2002). The infection with *Fasciola* sp. in deer was also observed by Maia (2001), Vengušt (2003), Chroust & Chroustova (2004), and Novobilsky et al. (2007). Comparatively, however, higher prevalence rate of *Fasciola* spp. in deer was recorded by Kanungo et al. (2010) as 20% at Dhaka Zoo and 19.1% at Dulahazara Safari Park. This difference might be due to location of animal cages, availability of intermediate hosts near the cages, and the source of feeds. The probable cause of *Fasciola* spp. infection was strongly connected with mud snails that live on the edges of drains and act as intermediate host (Vengust 2003). Another important factor was the green grass and leaves supplied to deer from outside of the zoo, which may be contaminated with metacercaria (Kanungo et al. 2010). At Bangabandhu Sheikh Mujib Safari Park, the chance of contamination is also higher as the cage is located at marshy land and the grass supplied to the deer is also taken from the outside.

Among primates, 70% of animals were infected with GI parasites. This result is much lower than that of Mutani et al. (2003) who revealed the overall infection rate was 88.7%. On the other hand, lower prevalence rate in primate was recorded by Lim et al. (2008) and Stuart et al. (1990) as 54.5% and 48%, respectively. The present study also confirmed that among the infected primate, there was a lower occurrence of protozoa (20%) than helminth (40%) which is against the earlier report of Lim et al. (2008) who recorded as 35.4% protozoa and 19.1% helminths. *Balantidium coli* were the most prevalent intestinal parasite detected in primates. This finding is an agreement with the earlier report of Levecke et al. (2007). Actually, *Balantidium coli* are common protozoa of animals having a wide host range and possess a simple direct life cycle. The appearance of these parasites can be explained by the simplicity of their life cycle, the low infective dose, the short pre-patent period and ability to survive in the environment.

CONCLUSIONS

Though there are some coprology studies of GI parasites that have been done in wild animals in different zoos in Bangladesh, this is the first investigation on GI parasites in animals in Bangabandhu Sheikh Mujib Safari Park. Routine monitoring of the presence of parasites in animals and birds are imperative in assisting good management and implementation of preventive and control measures against the spread of infectious parasitic diseases among animals within the park or to humans.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17895–17905
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6662.13.3.17895-17905
#6662 | Received 10 September 2020 | Final received 02 November 2020 | Finally accepted 24 February 2021
PLATINUM OPEN ACCESS
COMMUNICATION

A rapid assessment of waterbirds and the mangrove status in the Menabe Antimena Protected Area, Madagascar

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Abstract: Mangroves are of great ecological importance that provide multiple ecosystem services, shelter, and habitat for many threatened waterbird species. The mangroves of the Menabe Antimena Protected Area (MANAP) in western Madagascar are among the most extensive remaining on the island. The remaining dryland forests of the MANAP have been subjected to immense deforestation in recent years. Although remote sensing studies indicate that the mangrove forest loss is considerably lower than the dryland forest loss, little is known about the mangroves' degradation status. Furthermore, detailed information on bird diversity and numbers is scattered, and previous surveys focused on northern parts of the MANAP, recently designated as the Wetlands of the Tsiribihina RAMSAR site. This study aims to assess bird diversity and abundance, as well as the status of mangroves in the MANAP. We conducted a rapid survey using direct observations at three sites along the coastal regions of the MANAP from 24 Sep–2 Oct 2019. We recorded 71 species of birds in the mangroves and coastal wetlands. High numbers of individuals were counted for several species. Numbers of the Madagascar Plover *Charadrius thoracicus* and the Madagascar Teal *Anas bernieri* fulfill criteria for important bird areas at single survey sites and the site is likely to be of importance for Madagascar Sacred Ibis *Threskiornis bernieri*; these three species are all globally threatened. Mangrove degradation is still limited, but numerous threats to mangroves are present. Our results highlight the importance of the mangroves of the MANAP for several endemic bird species in Madagascar. We provide recommendations for conservation management and future research.

Keywords: Mangrove quality, Madagascar Heron, Madagascar Plover, Madagascar Sacred Ibis, Madagascar Teal.

Résumé: Les mangroves sont d'une grande importance écologique et fournissent de multiples services écosystémiques, un abri et un habitat pour de nombreuses espèces d'oiseaux d'eau menacées. Les mangroves de l'Aire Protégée de Menabe Antimena (APMA) dans l'ouest de Madagascar sont parmi les plus étendues qui subsistent sur l'île. Les forêts sèches restantes de l'APMA ont été soumises à une immense déforestation ces dernières années. Bien que les études de télédétection indiquent que la perte de la forêt de mangrove est considérablement plus faible que celle de la forêt sèche, on sait peu de choses sur l'état de dégradation des mangroves. En outre, les informations détaillées sur la diversité et le nombre d'oiseaux sont éparses, et les enquêtes précédentes se sont concentrées sur les parties nord de l'APMA, récemment désignées comme les zones humides du site RAMSAR de Tsiribihina. Cette étude vise à évaluer la diversité et l'abondance des oiseaux, ainsi que l'état des mangroves dans le APMA. Nous avons mené une enquête rapide en utilisant des observations directes sur trois sites le long des régions côtières de l'APMA du 24 septembre au 2 octobre 2019. Nous avons enregistré 71 espèces d'oiseaux dans les mangroves et les zones humides côtières. Des nombres élevés d'individus ont été comptés pour plusieurs espèces. Les nombres de Pluvier de Madagascar Charadrius thoracicus et de Sarcelle de Madagascar Anas bernieri remplissent les critères des zones importantes pour les oiseaux sur des sites d'enquête uniques et le site est susceptible d'être important pour l'Ibis sacré de Madagascar Threskiornis bernieri ; ces trois espèces sont toutes menacées au niveau mondial. La dégradation de la mangrove est encore limitée, mais de nombreuses menaces pèsent sur les mangroves. Nos résultats soulignent l'importance des mangroves de l'APMA pour plusieurs espèces d'oiseaux endémiques de Madagascar. Nous fournissons des recommandations pour la gestion de la conservation et les recherches futures.

Editor: Anonymity requested. **Date of publication:** 26 March 2021 (online & print)

Citation: Zöckler, C., S.N. Razanamaheninina & M. Markolf (2021). A rapid assessment of waterbirds and the mangrove status in the Menabe Antimena Protected Area, Madagascar. *Journal of Threatened Taxa* 13(3): 17895–17905. https://doi.org/10.11609/jott.6662.13.3.17895-17905

Funding: Manfred Hermsen Stiftung; Stiftung Artenschutz; Chances for Nature.

Competing interests: The authors declare no competing interests.

For **Author details, Author contribution** & **Acknowledgements** see end of this article.

INTRODUCTION

Mangroves are among the most productive ecosystems on Earth (Clausen et al. 2010) and of great ecological importance (Carugati et al. 2018). While supporting high floral and faunal diversity, mangroves also provide essential products to humans, such as food, fuel, and various construction materials (Rasolofo 1997; Baba et al. 2013). Additionally, mangroves and its adjacent mudflats provide essential services to human coastal populations like water filtration, protection from storms, and coastal erosion (Jones et al. 2016). Finally, mangroves and mudflats contribute significantly to climate change mitigation via sequestering massive amounts of CO_2 (Sanderman et al. 2018). Despite their ecological importance, mangroves are subjected to various human pressures, and large areas of mangroves are converted to agricultural farmland or are overexploited for marine and forestry products. It is estimated that more than 35% of the world's mangroves have been lost since 2000 (Carugati et al. 2018).

Madagascar has approximately 2% of the world's mangroves and this represents the second largest extent of mangroves of any country in the western Indian Ocean (Shapiro et al. 2019). Most of Madagascar's mangroves are located along the western coast of the island. One of the most significant remaining mangrove areas is in the Menabe Antimena Protected Area (MANAP), covering approximately 13,000ha (Goodman et al. 2018). The MANAP is a protected area under IUCN category V (harmonious landscape). The dry forests of the MANAP have been subjected to drastic deforestation in recent years (Zinner et al. 2014; Hudson et al. 2019), and protection measures of dry forests are so far mostly ineffective. According to analysis of data on globalforestwatch.org, more than 65,000ha have been lost since 2001 (Global Forest Watch 2014; Zinner et al. 2014; Hudson et al. 2019), with annual deforestation rates up to 10%. Compared to dryland forest, mangrove loss in Madagascar seems to be considerably lower (around 2.4% from 2006 to 2016 in MANAP; Goodman et al. 2018) based on nationwide GIS analysis of mangrove dynamics using remote sensing imagery (Jones et al. 2016). The same study, however, indicates that the loss of mangrove forest within the Tsiribihina Manambolo Delta (which includes similar habitat to the north, net loss of 12,612ha, 38.4%) from 1990 to 2010 is one of the largest in Madagascar. Although such GIS-based studies are of considerable importance to mangrove mapping and conservation, remote sensing does not fully allow the assessment of mangrove degradation as it cannot distinguish specifically between naturally open-canopy mangrove areas and highly degraded areas (Hamilton & Casey 2016; Jones et al. 2016). Field-based surveys to assess threats and mangrove degradation or quality are, therefore, essential and contribute to a better understanding of mangrove dynamics and support conservation management decisions.

The mangroves and mudflats of the MANAP are an important refuge for numerous species (Goodman et al. 2018), including iconic and threatened species such as Madagascar Sacred Ibis *Threskiornis bernieri*, Madagascar Heron *Ardea humbloti*, Madagascar Teal *Anas bernieri*, and Madagascar Plover *Charadrius thoracicus*. Due to this diversity, parts of the mangroves of the MANAP are also declared as Important Bird Area (IBA), 'Wetlands of the Tsiribihina delta and upper Tsiribihina River' (WTDUTR) (BirdLife International 2020a), and have recently been designated as a Ramsar site 'Mangroves de Tsiribihina' (MdT) (Image 1). The MANAP includes a second RAMSAR site, the 'Wetlands of Bedo' or 'Lac Bedo'. The site is located in the centre of the Menabe region only a few kilometres from the coastline and represents an important site for animals, specifically for birds and fish.

In general, reliable data on bird distribution and abundance are rare for bird species in centralwestern Madagascar and are often based on patchy observations collected infrequently by different scientists, tourists or hunters (Young et al. 2014). Therefore, it is of great importance to regularly update numbers on the diversity and abundance of bird taxa.

Given the ecological importance of mangroves and the increased human pressure seen in recent years in the MANAP, our study aimed to quantify waterbird populations, mangrove condition, and threats to mangrove habitat and waterbird species within the protected area in order to contribute to future conservation management.

MATERIALS AND METHODS

Three distinct coastal wetlands (all consisting of mangroves and mudflats) were visited and surveyed (see Image 1) within the MANAP from 24 September–2 October 2019. The three sites were chosen to represent approximately the whole range of mangroves in the MANAP. Image 1 depicts bird records during the survey in September 2019. Site 1 Tsangajoly (Baie de Borongeny and Namangoa, lat. -19.830528, lon. 44.501139) is also part of the MdT Ramsar site and Important Bird Area

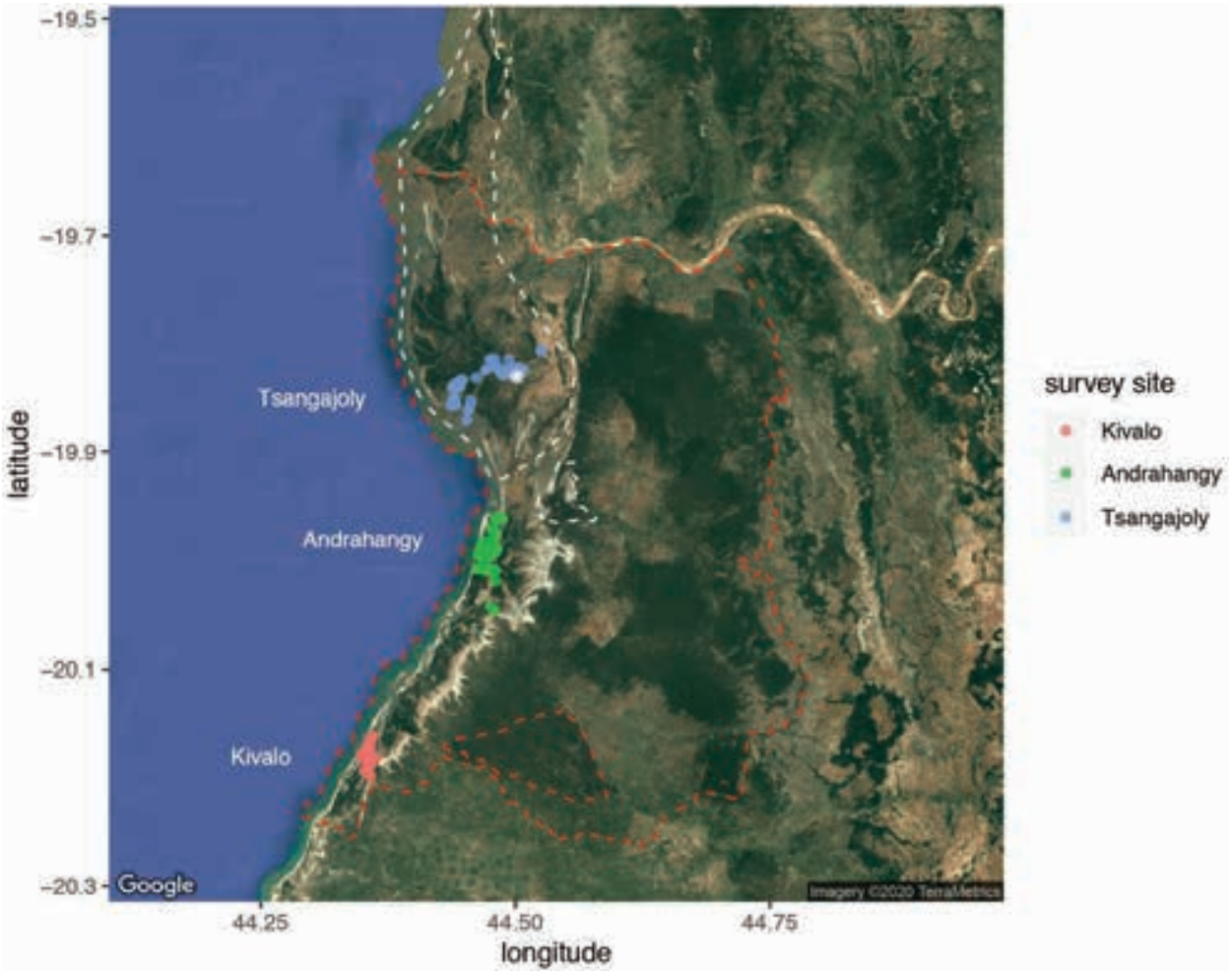

Image 1. Bird survey GPS points and three main observation areas: white dotted lines—Ramsar site boundaries (northern area= Wetlands of Tsiribihina, southern area= Lac Bedo south) | red-dotted line—boundary of Menabe Antimena Protected Area | *—Lodge de la Saline, each point can also represent multiple species of birds.

WDTUTR. This site has been surveyed for birds relatively recently (www.Ramsar.org) along with its designation as a Ramsar site. Surveys in Tsangajoly were started from the Lodge de la Saline, an abandoned shrimp farm that has been modified into an ecolodge with fantastic birdwatching opportunities. Given time constraints and relatively recent data for birds, we only focused on the southern third of the approximately 47,000 ha area. Site 2, Andrahangy (lat. -19.971611, lon. 44.466000), is south of the Tsiribihina delta and does not belong to the Ramsar site MdT. Site 3, Kivalo (lat. -20.208056, lon. 44.331361), is the most southern site visited within the MANAP.

Each area was surveyed using either a motorboat (site 1) or local dugout canoes (site 2 & 3). Observed birds were identified to the species level following Hawkins et al. (2015) and counted using binoculars. Several stops were conducted on mudflats or the shoreline to count large aggregations of waterbirds using a zoom telescope. Local fishermen were additionally interviewed for the presence and absence of certain key species and threats on an ad libitum basis.

Occurrence and abundance of waterbirds was compared and discussed in relation to relevant Ramsar criteria. The Ramsar Convention on Wetlands, signed in Ramsar, Iran, in 1971, provides nine criteria to use in the assessment and designation of Wetlands of International Importance. The Ramsar Criteria relevant to the assessment of the importance of the mangroves of the MANAP for waterbirds are as follows:

Criterion 2: A wetland should be considered internationally important if it supports Vulnerable, Endangered, or Critically Endangered species or threatened ecological communities.

Criterion 4: A wetland should be considered internationally important if it supports plant and/or

animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

The Ramsar convention came into force in Madagascar in 1999. Since then, Madagascar has designated an area of 2,147,911ha as wetlands of international importance.

Mangrove quality was assessed using a rapid assessment tool developed using a freely available custom-made application of the kobo toolbox (www.kobotoolbox.org). A detailed description of the method can be found in Zöckler et al. (2021). In short, the scale ranges from 1 (low quality) to 6 (high quality). Each level considers different aspects of mangrove degradation, such as shape, height, diameter at breast height (DBH) of remaining mangroves as well presence/absence of logging and percentage of light to floor. Bird occurrences and mangrove quality data were collected using a custom-made application (Android Open Data Kit/KoBo APP) using a smartphone. GPS precision was between 5 and 97 m with a mean of 26m. Maps and images were created using R version 3.5.3 (R Core Team 2019).

RESULTS

Bird diversity and abundance

We observed 71 species of birds (Annexe, Table 1). Of these, special attention was given to waterbirds and globally threatened species, some of which were found in high numbers at individual sites.

Globally threatened bird species

The survey revealed interesting new data points for several threatened species. Specifically, Andrahangy shows profound structural habitat variation, including lagoons, sandbanks, salt flats, and mudflats, interspersed into the mangroves. The area is likely to be very important for the Madagascar Plover *Charadrius thoracicus*. Both, the Madagascar Teal and the Madagascar Plover exceed the 1% Ramsar threshold at single sites, Tsangajoly and Andrahangy (see Table 1). Of the Madagascar Teal (Image 3) 30 individuals were observed at Tsangajoly (Image 4) and 26 Madagascar Plover (Image 5) at Andrahangy. Eight individuals of the Madagascar Heron were seen at Tsangajoly (Image 6 & 7).

Furthermore, we did not observe the Madagascar Sacred Ibis *Threskiornis berneri* and the Madagascar Fish Eagle *Haliaeetus vociferoides* in either of the survey areas. Although we could not observe this Ibis during the survey, interviews with local communities consistently revealed Andrahangy as the location where the Madagascar Sacred Ibis was most observed recently.

Important waterbird observations

Although none of the other waterbird species were observed in numbers over 1% of the flyway population (Wetlands International 2012) Whimbrel, Grey Plover, and Curlew Sandpiper were recorded for Madagascar in comparatively large numbers (Safford & Hawkins 2013). Almost 2,000 Whimbrel and 600 Grey Plover were counted at Tsangajoly on 25 and 26 of September. The observation of 130 Bar-tailed Godwits on 25 September in Tsangajoly is exceptional and noteworthy. In the same area were large numbers of terns (both Common and Roseate Terns plus a few Lesser and Greater Crested Terns) of over 3,500 individuals on 26 September. Such high numbers were not observed at the same site the day before. It might be possible that these large gatherings coincide with certain tidal cycles and could be easily missed when surveying at different tides.

In Andrahangy, the most common waterbird was the Curlew Sandpiper with over 2,200 individuals. A more thorough survey of additional intermediary sites between the survey areas might yield much higher counts in numbers potentially significant for the flyway population beyond the 1% flyway threshold of 4,000 birds.

Mangrove quality

Image 2 shows the results of the three areas surveyed within the MANAP and the scale of the mangrove quality assessment ranging from 1–6. The average mangrove quality varies but ranges were still relatively high (Table 2) at all three sites, indicating an overall good quality of mangroves. Threats and losses, however, were identified and observed. The area around Tsangajoly appears least degraded. Some cutting by local people was observed at several sites, and browsing by cattle and goats on the edges impacts the mangroves' quality. In some cases, the mangroves have been heavily impacted and stunted by persistent browsing by livestock.

As well as being impacted by resource use of local communities, the mangroves at Tsangajoly were affected by the establishment of shrimp ponds by the company AQUAMEN; this led to the elimination of significant areas until shrimp production was abandoned in 2007 after a

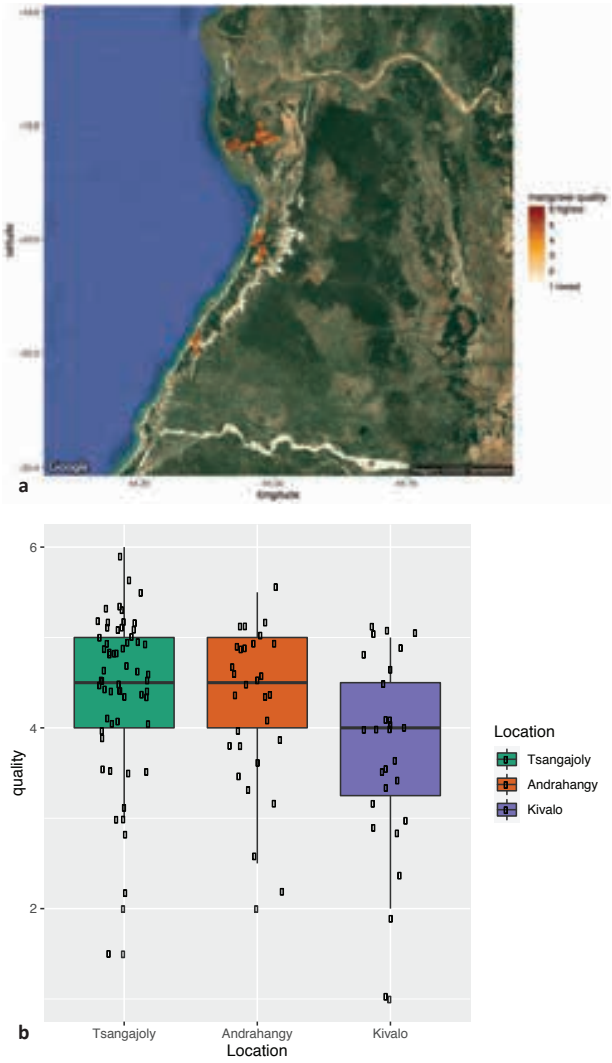

Image 2. a—survey sites for the mangrove quality/degradation assessment within the MANAP | b—visual comparison of mangrove quality among sites.

virus had infected all shrimps globally. The company created an eco-resort, Lodge de la Saline, which now offers fantastic birdwatching opportunities. The former shrimp ponds are now managed for waterbirds, and the owners have restored at least some of the areas where mangroves are recovering.

In Andrahangy and especially Kivalo, constant pressure from local people for construction wood and firewood has a visibly higher impact, resulting in a lower, but still reasonably high by national/global standards, average mangrove quality scores of 4.3 and 3.8, respectively, compared to 4.5 at Tsangajoly (see Table 1 and Image 2b). Details of the mangrove degradation assessment in the MANAP can be found in Zöckler et al. (2021).

Image 3. Madagascar Teal at Tsangajoly saline pond.

Image 4. Madagascar Teal and Lesser Flamingo at Tsangajoly saline pond.

Image 5. Madagascar Plover at Andrahangy.

Table 1. Distribution and abundance of birds recorded in the mangroves and mudflats of the MANAP during the survey period 24 Sep–2 Oct 2019; water birds exceeding 1% are indicated in bold letters.

	Family	Species	Scientific Name	Tsangajoly	Andrahangy	Kivalo	Total
1	**Anatidae**	**Madagascar Teal**	***Anas bernieri***	**30**	**2**	**0**	**32**
2	Anatidae	Red-billed Teal	*Anas erythrorhyncha*	15	0	0	15
3	Anatidae	White-faced Whistling-duck	*Dendrocygna viduata*	300	0	1	301
4	Apodidae	Madagascar Swift	*Cypsiurus parvus gracilis*	0	4	0	4
5	Caprimulgidae	Madagascar Nightjar	*Caprimulgus madagascariensis*	0	2	0	2
6	Burhinidae	Madagascar Pratincole*	*Glareola ocularis*	0	0	6	6
7	Charadriidae	Madagascar Three-banded Plover*	*Charadrius bifrontatus*	0	0	1	1
8	Charadriidae	Common Ringed Plover	*Charadrius hiaticula*	70	26	12	108
9	Charadriidae	Greater Sandplover	*Charadrius leschenaultii*	10	45	30	85
10	Charadriidae	White-fronted Plover	*Charadrius marginatus*	1	10	19	30
11	Charadriidae	Lesser Sand-Plover	*Charadrius mongolus*	35	2	0	37
12	Charadriidae	Kittlitz's Plover	*Charadrius pecuarius*	0	0	12	12
13	**Charadriidae**	**Madagascar Plover**	***Charadrius thoracicus***	**0**	**26**	**15**	**41**
14	Charadriidae	Pacific Golden Plover	*Pluvialis fulva*	0	1	0	1
15	Charadriidae	Grey Plover	*Pluvialis squatarola*	600	80	2	682
16	Dromadidae	Crab-plover	*Dromas ardeola*	0	24	0	24
17	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	120	0	2	122
18	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	20	20	40	80
19	Scolopacidae	Ruddy Turnstone	*Arenaria interpres*	10	10	12	32
20	Scolopacidae	Sanderling	*Calidris alba*	15	8	4	27
21	Scolopacidae	Curlew Sandpiper	*Calidris ferruginea*	170	2200	300	2670
22	Scolopacidae	Bar-tailed Godwit	*Limosa lapponica*	130	0	0	130
23	Scolopacidae	Whimbrel	*Numenius phaeopus*	1900	100	25	2025
24	Scolopacidae	Common Greenshank	*Tringa nebularia*	90	25	0	115
25	Scolopacidae	Terek Sandpiper	*Xenus cinereus*	158	21	9	188
26	Laridae	Grey-headed Gull	*Chroicocephalus cirrocephalus*	2	0	0	2
27	Sternidae	Caspian Tern	*Hydroprogne caspia*	41	0	0	41
28	Sternidae	Lesser Crested Tern	*Sterna bengalensis*	102	0	0	102
29	Sternidae	Greater Crested Tern	*Sterna bergii*	80	0	0	80
30	Sternidae	Common Tern	*Sterna hirundo*	3010	0	0	3010
31	Sternidae	Roseate Tern	*Sterna roseata*	436	0	0	436
32	Sternidae	Saunders's Tern	*Sternula saunderi*	0	1	3	4
33	Ardeidae	Great White Egret	*Ardea alba*	60	0	0	60
34	Ardeidae	Grey Heron	*Ardea cinerea*	6	1	0	7
35	Ardeidae	Madagascar Heron	*Ardea humbloti*	8	0	0	8
36	Ardeidae	Purple Heron	*Ardea purpurea*	1	0	0	1
37	Ardeidae	Striated Heron	*Butorides striata*	8	4	4	16
38	Ardeidae	Western Reef-egret	*Egretta garzetta gularis*	25	3	9	37
39	Ardeidae	*Little Egret*	*Egretta gazetta dimorpha*	60	4	5	69
40	Ciconiidae	African Openbill	*Anastomus lamelligerus*	0	0	2	2
41	Ciconiidae	Yellow-billed Stork	*Mycteria ibis*	1	0	0	1
42	Threskiornithidae	African Spoonbill	*Platalea alba*	6	0	0	6

	Family	Species	Scientific Name	Tsangajoly	Andrahangy	Kivalo	Total
43	Threskiornithidae	Glossy Ibis	*Plegadis falcinellus*	0	2	0	2
44	Columbidae	Madagascar Turtle-dove	*Nesoenas picturata*	0	0	+	0
45	Columbidae	Madagascar Green-pigeon	*Treron australis*	0	0	7	7
46	Columbidae	Namaqua Dove	*Oena capensis*	+	0	0	+
47	Alcedinidae	Madagascar Kingfisher	*Crythornis madagascariensis*	2	7	4	13
48	Meropidae	Olive Bee-eater	*Merops superciliosus*	2	7	5	14
49	Upupidae	Madagascar Hoopoe	*Upupa marginata*	0	0	1	1
50	Cuculidae	Madagascar Coucal	*Centropus toulou*	1	0	8	9
51	Cuculidae	Red-capped Coua	*Coua ruficeps*	0	0	1	1
52	Acciptridae	Black Kite	*Milvus migrans*	+	+	0	0
53	Acciptridae	Madagascar Harrier-hawk	*Poyboroides radiatus*	3	2	2	7
54	Falconidae	Madagascar Kestrel	*Falco newtoni*	0	1	0	1
55	Rallidae	White-throated Rail	*Dryolimnas curveri*	1	2	8+	11+
56	Turnicidae	Madagascar Buttonquail	*Turnix nigricollis*	4	0	2	6
57	Acrocephalidae	Madagascar Swamp-warbler	*Acrocephalus newtoni*	+	+	0	0
58	Cisticolidae	Common Jery	*Neomixis tenella*	+	+	+	0
59	Dicruridae	Crested Drongo	*Dicrurus forficatus*	+	3	0	3
60	Nectariniidae	Souimanga Sunbird	*Nectarina souimanga*	0	4	2	6
61	Ploceidae	Madagascar Fody	*Foudia madagascariensis*	+	0	0	0
62	Ploceidae	Madagascar Mannikin	*Lepidopygia nana*	+	0	0	+
63	Pycnonotidae	Madagascar Bulbul	*Hypsipetes madagascariensis*	0	+	+	0
64	Turdidae	Madagascar Magpie-robin	*Copsychus albospecularis*	+	0	+	0
65	Vangidae	White-headed Vanga	*Artamella viridis*	1	0	3	4
66	Vangidae	Sickle-billed Vanga	*Falculea palliata*	0	0	5	5
67	Vangidae	Common Newtonia	*Newtonia brunneicauda*	+	1	3	4
68	Phoenicopteridae	Lesser Flamingo	*Phoeniconaias minor*	120	0	0	120
69	Psittacidae	Grey-headed Lovebird	*Agapornis canus*	1	0	20	21
70	Psittacidae	Vasa Parrot	*Coracopsis sp.*	7	94	2	103
71	Strigidae	Madagascar Scops-owl	*Otus rutilus*	1	2	0	3
*not in mangroves but brackish water close to Baobab Amoreux/Mangily							

Table 2. Average mangrove quality in the MANAP in Sep 2019 (max. range 1–6).

	Site	Average (range) mangrove quality	No of mapped mangrove sites
1	Tsangajoly	4.5 (1.5–6.0)	59
2	Andrahangy	4.3 (2.0–5.5)	29
3	Kivalo	3.8 (1.0–5.0)	27

DISCUSSION

To the best of our knowledge, the mangrove quality assessment is the most detailed field-based assessment of mangrove quality in the region to date, and highlights the importance of the MANAP for conservation of this ecosystem in Madagascar. In the following, we briefly discuss our results in the light of Red Listed Species and species that qualify for the >1% Ramsar threshold at the three sites that were investigated.

Three bird species observed during our survey in the MANAP are listed as globally threatened and belong to the five (*Ardea humbloti*, *Anas bernieri*, *Haliaeetus vociferoides*, *Amaurornis olivieri*, *Cahradrius thoracicus*) restricted range species of global conservation concern that qualify the WTDUTR as Important Bird Area (Project Zicoma 2001).

The Madagascar Teal *Anas bernieri* is endemic to Madagascar and only distributed along the western coastal stretch of the island. It is assessed as per the IUCN

Image 6. Madagascar Heron at Tsangajoly saline ponds.

Image 9. Crab Plovers *Dromas ardeola* in Andrahangy.

Image 7. African Spoonbill, Grey-headed Gull, White-faced Whistling Duck, and Madagascar Heron in a former shrimp pond at the Lodge de la Saline.

Image 8. Madagascar Three-banded Plover *Charadrius bifrontatus* in brackish water close Baobab Amoreux.

Red List as globally 'Endangered' and with estimated 1,000–1,700 mature individuals (BirdLife International 2016a) possibly the most threatened species observed. The species is well known from the MANAP, specifically Lac Bedo, which is also designated as a Ramsar site. Our survey adds one more occurrence for the Madagascar Teal in Andrahangy, which is about 2km away from Lac Bedo. Young et al. (2014) counted several birds in the salines of Menabe coastal wetlands and warned about fragmentation of the population. In total, we counted 30 birds simultaneously at Tsangajoly (Lodge de la Saline). As the area is large and difficult to survey it is likely that more birds are present. Although it is known that the species occurs in loose groups of up to 40 individuals outside the breeding season, such a high number of individuals at one place suggests that the ponds of the Lodge de la Saline represent a crucial refuge for this species. The total amount of birds (32) equals 1.9–3.2 % of the estimated global population. Population size increased north of the MANAP at Manambolomaty between 1999–2011 (Razanfindrajao et al. 2017).

Madagascar (Black-banded) Plover *Charadrius thoracicus* is assessed as 'Vulnerable' on the IUCN Red List (BirdLife International 2020b). The species is confined to coastal habitats, and in total, we recorded at least 41 individuals in Andrahangy and Kivalo sandy mudflats. The total population has been estimated based on suitable habitat models at around 3,100 (2,700-3,500) individuals (Long et al. 2008); however, due to continuous habitat loss (Zefania & Skekely 2013), this number could already be very much lower today. According to the last IUCN Red List assessment, the 2008 estimate equates to between 1,800 and 2,300 mature individuals. Our 41 individuals, therefore, exceed the 1% (1.7–2.3 %) threshold of the global population of

this species. Individuals observed seem to prefer sandy mudflats only. The area visited in Tsangajoly estuary does not contain many of these habitats. Therefore, it was not surprising not to find the species here, although it was reported to occur in 2016 (www.Ramsar.org). Safford (1993) reported aggregations of (12 individuals) in the Tsiribihina delta as well. In Andrahangy, we recorded at least 26 different birds, all distributed in the southern part. Usually, the bird is observed in groups of 2–10 birds (BirdLife International 2020b), however, congregations of 26 and 15 respectively seem to be unusual and merit special attention. More detailed survey work is necessary and might reveal even higher numbers in the area. The coastal wetlands of the MANAP might be one of their main strongholds along Madagascar's western coast (Young et al. 2014).

Another endemic water bird in the area is the Madagascar Heron *Ardea humbloti*, listed as globally 'Endangered'. The species prefers coastal wetlands but has also been observed inland (Sartain & Hawkins 2013; BirdLife International 2020b). The total number of mature individuals is estimated at 1,000 (BirdLife International 2016b). A severe threat to this species is the replacement of suitable nesting trees around wetlands. Ten individuals have been reported at Lake Kimanaomby within the MANAP (Chechia 2020). In total, we observed eight birds, all in Tsangajoly (Lodge de la Saline) wetlands, which equals 0.8% of the global population; the true number using the area seems almost certain to exceed the 1% threshold. The species was also recorded in the Tsiribihina delta by Safford (1993) and in 2016 (Ramsar 2020).

Given the short time frame of the survey, this underlines the importance of the wetlands of the MANAP, specifically the lakes and the abandoned shrimp ponds of the Lodge de la Saline, for this species.

The latter applies as well to the Madagascar Fish-Eagle *Haliaeetus vociferoides* (CR) and potentially the Madagascar Sacred Ibis, which are known to exist but could not be recorded during our survey. The Madagascar Sacred Ibis was one of the species given special attention in this study. After consultation with local stakeholders and interviews with local villagers in preparation of the survey, two sites were specifically chosen for the search of this species.

Safford (1993) recorded 44 individuals in Tsiribihina delta and Baie de Borongeny accessed via Tsangajoly (site 1) was listed with 31 birds during the last published Ramsar designation survey in 2016 (Ramsar 2020). Andrianarimisa & Razafimanjato (2010) estimated the total population less than 2,000 individuals and listed 10 individuals from four sites within the MANAP. All interviewed villagers, even in a community at the shoreline of the Baie de Borongeny (site 1), consistently mentioned Andrahangy as the best place to see the Madagascar Sacred Ibis. In general, interviews revealed that the species exists at all three locations. In Andrahangy, a fisherman reported a sighting earlier the same day, however, we were not able to confirm this observation. Although its presence was broadly confirmed by local fishermen, not detecting the species during our survey could be due to its seasonal secretive behaviour, but also due to relatively low numbers of individuals. Interviews suggest the species is still present in the surveyed areas, but challenging and irregularly observed. As the species is most vocally active during the breeding season and roosts in small colonies (Safford & Hawkins 2013), a future survey should be conducted during the breeding and wet season in November–April to increase the chance of detecting the species. Interviews with local fishermen did not reveal any species-specific threats, such as collecting eggs in the area. Egg collection is known to be a major threat for water birds in the MANAP (PAG Menabe Antimena 2014). Individual answers, however, might be influenced by the anxiety of the person interviewed of potential punishment for conducting illegal activity in the PA. As this species is very difficult to confuse with any other species (at least when not in flight), monitoring by community members might be a good solution to conduct surveys more regularly in the future. Overall, our numbers of waterbirds (Tsangajoly >7500; Andrahangy > 2500; Kivalo ~500) is comparable to survey estimates of other IBAs in the Antsalova region further north, specifically the Bemamba and Manambolomaty wetland complex, where waterbird numbers range 266–4,105 across survey sites (see Razafimanjato et al. 2007; Table 1).

Recommendations

We recommend several measures to improve waterbird and mangrove conservation in the area. More emphasis should be put on raising environmental awareness in local communities of the importance of the mangroves for people and nature. Mangrove communities should be included in existing training programs to transfer knowledge of sustainable resource use. For example, mangrove cutting for firewood is a significant driver of mangrove degradation and could be decreased by promoting fuel-efficient stove solutions.

Furthermore, our rapid survey revealed mangrove degradation details, which cannot be achieved using

remote sensing technologies. This knowledge is essential for identifying important sites for mangrove restoration as degraded mangroves can be restored much more easily than those already destroyed. It is, therefore, recommended to extend the degradation assessment to the remaining wetlands in Menabe.

More survey work is needed for the Andrahangy and Kivalo areas which currently lie outside existing Ramsar sites, as they seem to be important for Madagascar Plover, Madagascar Teal, potentially the Madagascar Sacred Ibis, and the Curlew Sandpiper, of which more than 2,000 individuals were counted at Andrahangy alone. It is worth considering an extension of the existing Ramsar site to include the Andrahangy and Kivalo area into the Ramsar site network. Both sites contained mangroves with low levels of degradation. Community projects have been initiated in Kivalo and Andrahangy. Both of them are still running and should be strengthened in the future. Both sites offer excellent opportunities for community-based tourism, but implementation appeared difficult on site, however, additional concepts for conservation benefits of local fishermen have to be developed. The ongoing covid19 crisis shows that community-based tourism should not be the only alternative income strategy for local communities supporting conservation.

The Lodge de la Saline (previously AQUAMEN) at Tsangajoly, a former shrimp farming company that has been turned into a private protected area, seems to be a significant site for the future management of several endemic threatened bird species in the area. Therefore, it is recommended to ensure strong collaboration with the owners and consider integrating the abandoned shrimp ponds to waterbird conservation measures.

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Acknowledgements: We are very grateful for the financial support of the Stiftung Artenschutz and the Manfred-Hermsen-Foundation. We thank Leon Razafimanantsoa, Rodin Rasoloarison, Dannick Randriamanantena, Sama Zefania, Remis d'Ampataka and numerous local guides for sharing information and logistic support during and ahead of the survey. Roger Safford provided intimate site knowledge and logistical advice. We thank Aristide Andrianarimisa and Roger Safford for very helpful comments on earlier versions of this manuscript. We are grateful as well to the Direction Regionale de Ministère de l'Environnement et du Developpement Durable for the permission of the survey (CAFF/CORE: N°206/19).

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17906–17917
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.4733.13.3.17906-17917
#4733 | Received 28 November 2019 | Final received 14 October 2020 | Finally accepted 04 March 2021
PLATINUM OPEN ACCESS
COMMUNICATION

An appraisal of avian species diversity in and around Purulia Town, West Bengal, India

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Abstract: Purulia, the westernmost district of West Bengal, India is least explored with respect to the biological diversity and relatively little information is available to date. The present study was conducted from February 2017 to January 2018 to document avifaunal diversity in Purulia Town and surroundings. Sampling was done through the line transect method with photographic documentation and subsequent identification following suitable keys. Species richness and seasonal abundance were calculated. Altogether, 115 species of birds belonging to 19 orders and 43 families were recorded during the study period. Passeriformes was the most dominant order represented by 46 species during the study. The Shannon-Wiener (H') value was highest for January (1.564). A large number of migratory birds visit Purulia every year mostly during winter and it is reflected in the present study. Diverse foraging habit among the birds was observed during the study period and omnivorous birds (29%) were found in highest number followed by invertivores (26%), carnivores (25%), granivores (8%), herbivores (7%), frugivores (3%), and nectarivores (2%). The present study is a preliminary effort to document the avifaunal diversity of Purulia and a more extensive systematic study should be carried out to investigate and protect the avifaunal diversity of this region.

Keywords: Bird, feeding guild, species diversity, species richness.

Bengali: পশ্চিমবঙ্গ রাজ্যের একেবারে পশ্চিমপ্রান্তে অবস্থিত পুরুলিয়া জেলার জীববৈচিত্র্য নিয়ে এখনও পর্যন্ত খুব কমই গবেষণা হয়েছে। তাই এই বিষয়ে তথ্যের অভাব রয়েছে। পুরুলিয়া শহর ও তার পার্শ্ববর্তী এলাকায় পাখির বৈচিত্র্য সম্বন্ধে তথ্য সংগ্রহের উদ্দেশে ২০১৭ সালের ফেব্রুয়ারী মাস থেকে ২০১৮ সালের জানুয়ারী মাস পর্যন্ত একটি সমীক্ষা করা হয়। সমীক্ষাতে পাখি গণনার জন্য "line transect" পদ্ধতি অনুসরণ করা হয় এবং ক্যামেরার সাহায্যে ছবি তুলে পাখি সনাক্ত করণেরউপযুক্ত বিধি মেনে পাখিগুলিকে সনাক্ত করা হয়। প্রজাতি প্রাচুর্য ও ঋতুগত তারতম্য হিসাব করা হয়। সমীক্ষার সময়কালে ১৯ টি বর্গ ও ৪৩ টি গোত্রের অন্তর্গত সর্বমোট ১১৫ টি প্রজাতির পাখি নথিভুক্ত করা হয়। Passeriformes বর্গের অধীনে সর্বোচ্চ ৪৬ টি প্রজাতির পাখি নথিভুক্ত করা হয়। জীববৈচিত্র্য নির্দেশক Shannon-Wiener (H') সূচক জানুয়ারী মাসে সর্বোচ্চ (1.564) ছিল। প্রত্যেক বছর শীতকালে প্রচুর পরিযায়ী পাখি পুরুলিয়া জেলাতে আসে যা বর্তমান সমীক্ষাতেও প্রতিফলিত হয়েছে। নথিভুক্ত পাখিগুলির মধ্যে খাদ্যাভাস এর বিভিন্নতা পরিলক্ষিত হয়েছে। এদের মধ্যে সর্বভুক প্রকৃতির পাখি ছিল সর্বাধিক (২৯%), তাছাড়াও অমেরুদণ্ডীভুক (২৬%), মাংসাশী (২৫%), দানাশস্যভুক (৮%), শাকাহারী (৭%), ফলাহারী (৩%) এবং পরাগভুক (২%) খাদ্যাভাস যুক্ত পাখিও পাওয়া গেছে। বর্তমান সমীক্ষাটি পুরুলিয়া শহর ও পার্শ্ববর্তী এলাকার পাখির বৈচিত্র্য নথিভুক্ত করার একটি প্রাথমিক প্রচেষ্টা। এই অঞ্চলের পাখিসহ অনান্য জীববৈচিত্র্য সংরক্ষণের জন্য আরও বিস্তারিত ও সংগঠিত সমীক্ষা ও গবেষণার প্রয়োজন রয়েছে।

Editor: C. Srinivasulu, Osmania University, Hyderabad, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Mahato, S., S. Mandal & D. Das (2021). An appraisal of avian species diversity in and around Purulia Town, West Bengal, India. *Journal of Threatened Taxa* 13(3):17906–17917. https://doi.org/10.11609/jott.4733.13.3.17906-17917

Funding: Self funded.

Competing interests: The authors declare no competing interests.

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Author contribution: SM—field work, photographic documentation, literature review and proof reading. SM—study design, plan of work, literature review, manuscript writing and proof reading. DD—literature review, statistical analysis, manuscript writing and proof reading.

Acknowledgements: The authors are grateful to the Principals of Jagannath Kishore College, Purulia; Bangabasi College, Kolkata and Bagnan College, Howrah, West Bengal for granting necessary permissions and providing facilities to carry out the research work. The authors would also like to appreciate the help and support rendered by Dr. Partha Pratim Saha and Mr. Supriya Samanta during the study.

INTRODUCTION

About 10,721 species of birds are living in this planet (Billerman et al. 2020) distributed from the polar regions to the tropical forests and are even prominent in the highly populated metropolitan cities. Approximately, 75% and 45% of total bird species around the globe are adapted to forest habitats and human-modified habitats, respectively (BirdLife International 2018), where they play important role in pollination, seed dispersal, pest control, and act as an indicator of a healthy environment (Hadley et al. 2012; Ramachandra 2013). Birds play a crucial role in plant pollination; through their faeces, they carry seeds and initialize the distribution of plants to distant places; act as scavengers, which help in ecological decomposition. Birds are considered good ecological indicators as they exploit all trophic levels in a food chain acting as herbivore, carnivore, or omnivore. They respond to the qualitative and/or quantitative changes in the environment and usually indicate the secondary changes in their surroundings (Morrison 1986; Koskimies 1989). Population dynamics of bird species may indicate natural disasters like drought (Blake et al. 1994) or anthropogenic stress like the introduction of new species in the ecosystem and urbanization (Savidge 1984; O'Connell et al. 2000).

Habitat loss is one of the key factors responsible for the rapid decline of the avian species population (Prasad et al. 2014). Anthropogenic activities like agriculture, urbanization, and firewood collection have contributed to deforestation and the simultaneous habitat degradation of the bird communities that affect the variety and variability of bird population (Storch et al. 2003). Understanding the changes in the diversity and abundance of the birds linked with the degradation of the natural habitats and ecosystems could help in framing necessary conservation actions.

Avian species diversity and distribution are not consistent with the landscape (Bibby et al. 1992). The pattern of biodiversity changes with environmental factors, climatic conditions, topography and habitats (Rodríguez-Estrella 2007; Jankowiski et al. 2009). Purulia is the westernmost district of West Bengal, India, and is topographically an undulated land which is the eastern part of Chotanagpur plateau. This district faces severe water scarcity in summer. Plants like Palash *Butea monosperma*, Kusum *Schleichera oleosa*, Mahua *Madhuca longifolia*, Neem *Azadirachta indica*, Kend *Diospyros melanoxylon*, Haritaki *Terminalia chebula*, Amla *Phyllanthus emblica*, Karange *Pongamia pinnata*, Bamboo *Bambusa* spp. which can tolerate drought, flourish in this district (Das 2016; Samanta et al. 2017). Purulia has been least explored concerning the biological diversity and relatively little published information is available to date (Das 2016; Samanta et al. 2017; Das 2018). In this circumstance, to enrich the knowledge on the biodiversity profile, an attempt was made to update the information about birds of Purulia Town and surroundings for the diversity and seasonal abundance. The main objective of the study was to determine bird species diversity and abundance to prepare a checklist of birds as well as to create awareness among the local people of Purulia to help maintain the ecological balance.

MATERIALS AND METHODS

Study Site

The present study was carried out to document the avifaunal diversity from February 2017 to January 2018 in and around Purulia Town (23.33 N; 86.36 E), Purulia, West Bengal, India. Five locations, namely, Ketika, Sidho-Kanho-Birsha University campus, Saheb Bandh, Surulia Deer Park, and Kansai river-side, situated in and around the town were selected for the study (Fig. 1). Ketika, situated about 2km from Purulia railway station, is a well-wooded residential area with trees, bushes, open lands with intermittent small ponds, and ditches. Sidho-Kanho-Birsha University campus is a vast open land with scattered bushes and trees. Saheb Bandh is a large man-made lake with some vegetation surrounding it. Surulia Deer Park is an urban forest with a mini zoo inside it. Kansai river-side was the area around the bank of river Kansai flowing by the south boundary of the town.

Data collection

Each study site was visited once a month. Line transect method was employed to record avifaunal richness and abundance (Hutto et al. 1986; Bibby et al. 1992; Buckland et al. 2004). The field surveys were conducted at 06.30–07.30 h, 12.00–13.00 h, and 16.30–17.30 h, and the values were averaged to obtain representative data of a particular count (Gibbons & Gregory 2006).

From the starting spot of any predetermined route, the bird species or their calls were recorded along either side of the transect. The starting point and the direction of transects were often random. The length of the route often varied due to topography, roads, water body that limited access. The opportunistic counts of birds during other times and other places were also included to

Figure 1. Study sites (marked by red circles) under present investigation in and around Purulia Town, West Bengal, India.

document a comprehensive checklist (Hossain & Aditya 2016).

Following visual observation or hearing a bird's call the presence of the birds was confirmed with the help of a binocular (Olympus 8 × 40 DPS1) and photographs were taken with digital cameras (Nikon Coolpix P520 and Canon 1200d, 55–250mm lens). Based on the visual observations and photographs, birds were identified following standard guidebooks (Ali 2002; Grimmett et al. 2011). Monthly data obtained from the one-year study was divided into four seasons: summer (March to May), monsoon (June to August), post-monsoon (September to November), and winter (December to February) to compare seasonal variations in avian species richness and abundance.

Species richness and diversity were calculated using Biodiversity Pro software (McAleece et al. 1997). The bird species diversity was calculated using the Shannon-Wiener diversity index [$H' = \sum p_i \ln p_i$] and Shannon diversity index [$H_{max} = Log_{10}(S)$]. Measurement of Shannon's evenness index was calculated using the following formula $J = H'/ H_{max}$ (p_i = proportion of total sample belonging to i^{th} species, S = total number of species in habitats (species richness) (Magurran 2004).

Migratory status and feeding habits of the enlisted birds was determined by personal observation as well as information available in the literature (Ali 2002; Grimmett et al. 2011; Birdlife International 2018).

RESULTS

In the present study, 115 species of birds consisting of 19 orders and 43 families were recorded in and around Purulia Town (Table 1; Image 1a, b). Passeriformes was found to be the most dominant order represented by 46 species (Fig. 2). Among the families, Anatidae was represented by the highest of nine species (Table 1). The residential status of the recorded birds shows that 78 species of birds were a permanent resident of Purulia, 36 bird species were winter migrants, and only one species Jacobin Cuckoo *Clamator jacobinus* was a summer migrant (Table 1). Among the winter migrants, Red-Crested Pochard *Netta rufina*, Northern Shoveler *Anas clypeata*, Garganey *Spatula querquedula*, Eurasian Wigeon *Mareca penelope*, Northern Pintail *Anas acuta*, Gadwall *Mareca strepera*, and Ferruginous Duck *Aythya nyroca* took shelter in the Saheb Bandh, Purulia. Among the 115 species of birds, 43 species were partly or completely dependent on water bodies.

The species richness value was highest in the winter season (104) and in December (99); whereas, this was lowest in Monsoon (69) and in August (61) (Table 4). The overall avian diversity index (H') for the town and surroundings was 3.66. The biodiversity index was also calculated month-wise (Fig. 3) and it depicts that the Shannon-Wiener (H') value was highest for January (1.564) though the H' value does not differ significantly for the rest of the months. Shannon evenness (J') value was lowest in December (0.767) and highest for July (0.857).

Feeding guilds included invertivorous, granivorous, nectarivorous, frugivorous, omnivorous, carnivorous, and herbivorous categories (Table 1, Fig. 4). Among the invertivorous birds, insectivorous and molluscivorous species specialized for feeding on only insects and mollusks (Table 1, Fig. 4) were considered. Omnivorous birds (29%) were found in the highest number followed by invertivores (26%), carnivores (25%), granivore (8%), herbivore (7%), frugivore (3%), and nectarivore (2%). Of all invertivores, insectivores represented 70% in number (Fig. 4).

DISCUSSION

As evident from the present study, Purulia Town and its surrounding places nurture a widely diversified

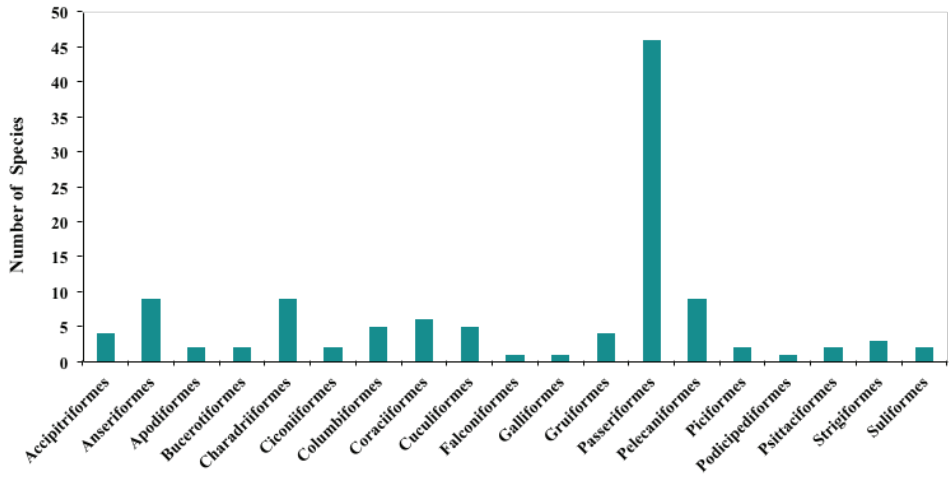

Figure 2. Family wise abundance (according to the number of species) of the birds observed during the present study.

Figure 3. Month-wise Shannon-Wiener index and evenness value of the birds observed.

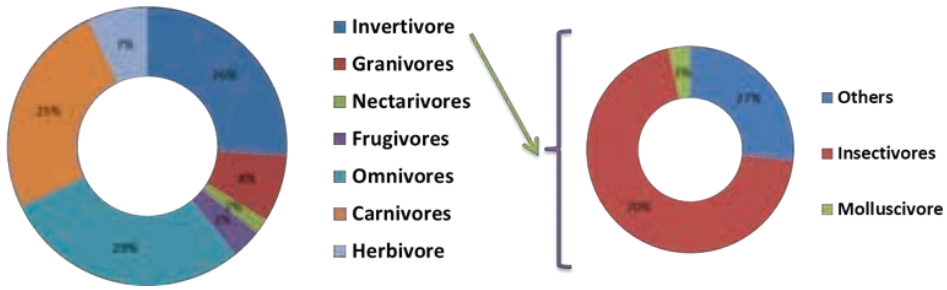

Figure 4. Feeding guild of the birds recorded in the present study.

avian group with its arid environment, wild flora, the fragmented agricultural field, plantation, and gardens that provides a complex landscape. The study area is moderately rich with its avifauna with 115 species, and when compared with previous observations in different parts of India it has been found that the species richness at Purulia (Table 2) was lower than the values reported for Burdwan (144) (Hossain & Aditya 2016), and the surrounding area of western Kachchh (252) (Gajera et al. 2013). But the avian diversity was higher than that reported for Kolkata surroundings (48 species) (Sengupta et al. 2014). Shannon diversity index (H') for the present study (3.66) was found to be higher than the Silent Valley (3.3) and moist deciduous forest of Mukkali (3.45) (Jayson & Mathew 2000), which indicates that Purulia Town possesses a rich avian diversity.

The present species richness value is greater than the richness values for Purulia Saheb bandh (24 species)

Table 1. Checklist of birds found in Purulia Town and surroundings with their seasonal occurrence, residential status, species abundance (P_i value), and feeding habits.

	Scientific name	Common name	Seasonal occurrence#	Status^	P_i value*	Feeding habit$
ORDER 1 : Accipitriformes						
Family: Accipitridae						
1	*Accipiter badius* (Gmelin, 1788)	Shikra	ALL	R	0.00173	C
2	*Milvus migrans* (Boddaert,1783)	Black Kite	ALL	R	0.00479	C
3	*Pernis ptilorhynchus* (Temminck, 1821)	Oriental Honey Buzzard	S, W	R	0.00005	C
4	*Circus aeruginosus* (Linnaeus, 1758)	Western Marsh Harrier	W	WM	0.00002	C
ORDER 2 : Anseriformes						
Family: Anatidae						
5	*Dendrocygna javanica* (Horsfield, 1821)	Lesser Whistling Duck	ALL	R	0.12926	G
6	*Netta rufina* (Pallas, 1773)	Red-Crested Pochard	S, PM, W	WM	0.01085	G
7	*Nettapus coromandelianus* (Gmelin, 1789)	Cotton Pygmy Goose	ALL	WM	0.00191	H
8	*Anas clypeata* (Linnaeus, 1758)	Northern Shoveler	S, PM, W	WM	0.00511	O
9	*Spatula querquedula* (Linnaeus, 1758)	Garganey	S, W		0.00041	O
10	*Mareca penelope* (Linnaeus, 1758)	Eurasian Wigeon	PM	WM	0.00002	H
11	*Anas acuta* (Linnaeus, 1758)	Northern Pintail	S, PM, W	WM	0.00702	H
12	*Mareca strepera* (Linnaeus, 1758)	Gadwall	S, PM, W	WM	0.00629	H
13	*Aythya nyroca* (Güldenstädt, 1770)	Ferruginous Duck	W		0.00010	O
ORDER 3: Apodiformes						
Family: Apodidae						
14	*Cypsiurus balasiensis* (J.E. Gray, 1829)	Asian Palm Swift	ALL	R	0.01229	I
15	*Apus affinis* (JE Gray, 1830)	Little Swift	ALL	R	0.01775	I
ORDER 4 : Bucerotiformes						
Family: Upupidae						
16	*Upupa epops* (Linnaeus, 1758)	Common Hoopoe	ALL	R	0.00049	I
Family: Bucerotidae						
17	Ocyceros birostris (Scopoli, 1786)	Indian Grey Hornbill	W	R	0.00002	F
ORDER 5 : Charadriiformes						
Family: Charadriidae						
18	*Charadrius dubius* (Scopoli, 1786)	Little Ringed Plover	M, PM, W	R	0.00215	IV
19	*Vanellus indicus* (Boddaert, 1783)	Red-wattled Lapwing	S, W	R	0.00044	IV
20	*Vanellus malabaricus* (Boddaert, 1783)	Yellow-wattled Lapwing	ALL	R	0.00367	IV
Family: Jacanidae						
21	*Hydrophasianus chirurgus* (Scopoli, 1786)	Pheasant-tailed Jacana	ALL	R	0.00338	IV
22	*Metopidius indicus* (Latham, 1790)	Bronze-winged Jacana	ALL	R	0.00605	O
Family: Scolopacidae						
23	*Actitis hypoleucos* (Linnaeus, 1758)	Common Sandpiper	W	WM	0.00018	C
24	*Gallinago gallinago* (Linnaeus, 1758)	Common Snipe	S, W	WM	0.00128	O
25	*Calidris temminckii* (Leisler, 1812)	Temmnick's Stint	W	WM	0.00175	IV
Family: Laridae						
26	*Gelochelidon nilotica* (Gmelin, 1789)	Gull-billed Tern	PM,W	WM	0.00167	I
ORDER 6 : Ciconiiformes						
Family: Ciconiidae						
27	*Anastomus oscitans* (Boddaert, 1783)	Asian Openbill-Stork	ALL	R	0.01043	M
28	*Leptoptilos javanicus* (Horsfield, 1821)	Lesser Adjutant	S, M, W	R	0.00023	C

	Scientific name	Common name	Seasonal occurrence#	Status^	P_i value*	Feeding habit$
ORDER 7 : Columbiformes						
Family: Columbidae						
29	*Columba livia* (Gmelin, 1789)	Rock Pigeon	ALL	R	0.04163	G
30	*Spilopelia chinensis* (Scopoli, 1768)	Spotted Dove	ALL	R	0.01801	G
31	*Streptopelia decaocto* (Frivaldszky, 1838)	Eurasian Collared-Dove	ALL	WM	0.01599	G
32	*Streptopelia tranquebarica* (Hermann, 1804)	Red Turtle Dove	PM, W	R	0.00026	H
33	*Treron phoenicopterus* (Latham, 1790)	Yellow-footed Green Pigeon	ALL	R	0.00532	F
ORDER 8 : Coraciiformes						
Family: Alcedinidae						
34	*Alcedo atthis* (Linnaeus, 1758)	Small blue Kingfisher	ALL	R	0.00461	C
35	*Ceryle rudis* (Linnaeus, 1758)	Pied Kingfisher	ALL	R	0.00086	C
36	*Halcyon smyrnensis* (Linnaeus, 1758)	White-throated Kingfisher	ALL	R	0.00469	C
Family: Coraciidae						
37	*Coracias benghalensis* (Linnaeus, 1758)	Indian Roller	ALL	R	0.00364	C
Family: Meropidae						
38	*Merops orientalis* (Latham, 1802)	Green Bee-eater	S, PM, W	R	0.03565	I
Family: Campephagidae						
39	Coracina macei (Lesson, 1830)	Large Cuckooshrike	PM, W	R	0.00018	I
ORDER 9 : Cuculiformes						
Family: Cuculidae						
40	*Centropus sinensis* (Stephens, 1815)	Greater Coucal	W	R	0.00021	C
41	*Centropus bengalensis* (Gmelin, 1788)	Lesser Coucal	ALL	R	0.00154	C
42	*Clamator jacobinus* (Boddaert, 1783)	Jacobin Cuckoo	S, M, PM	SM	0.00013	O
43	*Hierococcyx varius* (Vahl, 1797)	Common Hawk-Cuckoo	ALL	R	0.00065	O
44	Eudynamys scolopaceus (Linnaeus, 1758)	Asian Koel	S, M, PM, W	R	0.00157	F
ORDER 10: Falconiformes						
Family: Falconidae						
45	*Falco tinnunculus* (Linnaeus, 1758)	Common Kestrel	W	R	0.00005	C
ORDER 11 : Galliformes						
Family: Phasianidae						
46	*Francolinus pondicerianus* (Gmelin, 1789)	Grey Francolin	S, PM, W	R	0.00123	G
ORDER 12 : Gruiformes						
Family: Rallidae						
47	*Amaurornis phoenicurus* (Pennant, 1769)	White-breasted Waterhen	ALL	R	0.00341	O
48	*Fulica atra* (Linnaeus, 1758)	Common Coot	ALL	R	0.00697	O
49	*Gallinula chloropus* (Linnaeus, 1758)	Common Moorhen	ALL	R	0.00521	O
50	*Porphyrio porphyrio* (Linnaeus, 1758)	Purple Swamphen	ALL	R	0.00875	O
ORDER 13 : Passeriformes						
Family: Alaudidae						
51	*Eremopterix griseus* (Scopoli, 1786)	Ashy-crowned Sparrow-lark	PM	WM	0.00026	O
Family: Cisticolidae						
52	*Orthotomus sutorius* (Pennant, 1769)	Common Tailorbird	S, M, PM	R	0.00225	O
53	*Prinia socialis* (Sykes, 1832)	Ashy Prinia	W	R	0.00010	O
54	*Cisticola juncidis* (Rafinesque, 1810)	Zitting Cisticola	PM, W	R	0.00118	I
Family: Corvidae						
55	*Corvus splendens* (Vieillot, 1817)	House Crow	ALL	R	0.02420	O

	Scientific name	Common name	Seasonal occurrence#	Status^	P_i value*	Feeding habit$
56	*Dendrocitta vagabunda* (Latham, 1790)	Rufous Treepie	ALL	R	0.00797	O
Family: Dicruridae						
57	*Dicrurus macrocercus* (Vieillot, 1817)	Black Drongo	ALL	R	0.02608	I
58	*Dicrurus aeneus* (Vieillot, 1817)	Bronzed Drongo	M	R	0.00005	I
Family: Estrildidae						
59	*Euodice malabarica* (Linnaeus, 1758)	Indian Silverbill	ALL	R	0.01814	O
60	*Lonchura punctulata* (Linnaeus, 1758)	Scaly-breasted Munia	ALL	R	0.01473	G
Family: Hirundinidae						
61	*Hirundo rustica* (Linnaeus, 1758)	Barn Swallow	S, W	WM	0.00133	I
62	*Ptyonoprogne concolor* (Sykes, 1832)	Dusky Crag Martin	W	WM	0.00078	I
Family: Laniidae						
63	*Lanius cristatus* (Linnaeus, 1758)	Brown Shrike	W	WM	0.00005	IV
64	*Lanius schach* (Linnaeus, 1758)	Long-tailed Shrike	W	WM	0.00013	IV
65	*Turdoides striata* (Dumont, 1823)	Jungle Babbler	ALL	R	0.03807	I
66	*Iduna caligata* (Lichtenstein, 1823)	Booted Warbler	W	R	0.00036	I
67	*Acrocephalus stentoreus* (Hemprich & Ehrenberg, 1833)	Clamorous Reed Warbler	PM, W	R	0.00010	I
Family: Motacillidae						
68	*Anthus rufulus* (Vieillot, 1818)	Paddyfield Pipit	ALL	R	0.00642	I
69	*Anthus hodgsoni* (Richmond, 1907)	Olive-backed Pipit	PM, W	WM	0.00097	O
70	*Anthus trivialis* (Linnaeus, 1758)	Tree Pipit	PM		0.00018	O
71	*Motacilla alba* (Linnaeus, 1758)	White Wagtail	ALL	WM	0.00571	C
72	*Motacilla cinerea* (Tunstall, 1771)	Grey Wagtail	S,W	WM	0.00149	I
73	*Motacilla citreola* (Pallas, 1776)	Citrine Wagtail	S, PM,W	WM	0.00217	C
74	*Motacilla flava* (Linnaeus, 1758)	Yellow Wagtail	S, W	WM	0.00212	O
Family: Muscicapidae						
75	*Copsychus saularis* (Linnaeus, 1758)	Oriental Magpie Rrobin	ALL	R	0.00791	I
76	*Ficedula albicilla* (Pallas, 1811)	Taiga Flycatcher	W	WM	0.00021	I
77	*Saxicoloides fulicatus* (Linnaeus, 1766)	Indian Robin	ALL	R	0.00333	O
78	*Saxicola maurus* (Pallas, 1773)	Siberian Stonechat	W	WM	0.00026	I
79	*Phoenicurus ochruros* (S.G. Gmelin, 1774)	Black Redstart	W	WM	0.00002	O
80	*Eumyias thalassinus* (Swainson, 1838)	Verditer Flycatcher	W	WM	0.00002	O
81	*Luscinia svecica* (Linnaeus, 1758)	Blue Throat	PM, W	WM	0.00178	O
Family: Nectariniidae						
82	*Cinnyris asiaticus* (Latham, 1790)	Purple Sunbird	ALL	R	0.00228	N
83	*Leptocoma zeylonica* (Linnaeus, 1766)	Purple-rumped Sunbird	ALL	R	0.00333	N
Family: Oriolidae						
84	*Oriolus kundoo* (Sykes, 1832)	Indian Golden Oriole	ALL	R	0.00440	O
85	*Oriolus xanthornus* (Linnaeus, 1758)	Black-hooded Oriole	ALL	R	0.00506	O
Family: Passeridae						
86	*Passer domesticus* (Linnaeus, 1758)	House Sparrow	ALL	R	0.00797	G
87	*Gymnoris xanthocollis* (Burton, 1838)	Chestnut Shouldered Petronia	PM	R	0.00002	H
Family: Ploceidae						
88	*Ploceus philippinus* (Linnaeus, 1766)	Baya Weaver	ALL	R	0.01324	G
Family: Pycnonotidae						
89	*Pycnonotus cafer* (Linnaeus, 1766)	Red-vented Bulbul	S, M, PM	R	0.00749	O
Family: Phylloscopidae						
90	*Phylloscopus trochiloides* (Sundevall, 1837)	Greenish Warbler	S, M	WM	0.00031	IV

	Scientific name	Common name	Seasonal occurrence#	Status^	P_i value*	Feeding habit$
Family: Sturnidae						
91	*Acridotheres ginginianus* (Latham, 1790)	Bank Myna	ALL	R	0.09439	O
92	*Acridotheres tristis* (Linnaeus, 1766)	Common Myna	ALL	R	0.07866	O
93	*Gracupica contra* (Linnaeus, 1758)	Asian Pied Starling	ALL	R	0.04719	O
94	*Sturnia malabarica* (Gmelin, 1789)	Chestnut-tailed Starling	ALL	R	0.00749	O
95	*Sturnia pagodarum* (Gmelin, 1789)	Brahminy Starling	ALL	R	0.00773	O
Family: Chloropseidae						
96	*Chloropsis jerdoni* (Blyth, 1844)	Jordan's Leafbird	PM, W	R	0.00073	O
ORDER 14 : Pelecaniformes						
Family: Ardeidae						
97	*Ardea alba* (Linnaeus, 1758)	Great White Egret	ALL	R	0.00086	C
98	*Ardea intermedia* (Wagler, 1827)	Intermediate Egret	S, W	R	0.00010	C
99	*Ardea purpurea* (Linnaeus, 1766)	Purple Heron	S, PM, W	R	0.00028	C
100	*Ardeola grayii* (Sykes, 1832)	Indian Pond Heron	ALL	R	0.01208	C
101	*Bubulcus ibis* (Linnaeus, 1758)	Cattle Egret	ALL	R	0.00975	C
102	*Egretta garzetta* (Linnaeus, 1766)	Little Egret	ALL	R	0.01491	C
103	*Nycticorax nycticorax* (Linnaeus, 1758)	Black-crowned Night Heron	ALL	R	0.00576	C
Family: Threskiornithidae						
104	*Pseudibis papillosa* (Temminck, 1824)	Red-Naped Ibis	ALL	WM	0.01030	C
105	*Threskiornis melanocephalus* (Latham, 1790)	Black-headed Ibis	ALL	WM	0.00870	I
ORDER 15 : Piciformes						
Family: Picidae						
106	*Dinopium benghalense* (Linnaeus, 1758)	Black-rumped Flameback Woodpecker	ALL	R	0.00099	I
Family: Megalaimidae						
107	*Psilopogon haemacephalus* (Statius Muller, 1776)	Coppersmith Barbet	S, PM, W	R	0.00401	F
ORDER 16 : Podicipediformes						
Family: Podicipedidae						
108	*Tachybaptus ruficollis* (Pallas, 1764)	Little Grebe	ALL	R	0.00388	C
ORDER 17 : Psittaciformes						
Family: Psittaculidae						
109	*Psittacula eupatria* (Linnaeus, 1766)	Alexandrine Parakeet	ALL	R	0.02168	H
110	*Psittacula krameri* (Scopoli, 1769)	Rose-ringed Parakeet	ALL	R	0.02003	H
ORDER 18: Strigiformes						
Family: Strigidae						
111	*Athene brama* (Temminck, 1821)	Spotted Owlet	ALL	R	0.00361	C
112	*Bubo bengalensis* (Franklin, 1831)	Indian Eagle-owl	S	R	0.00002	C
113	*Tyto alba* (Scopoli, 1769)	Barn Owl	ALL	R	0.00152	C
ORDER 19: Suliformes						
Family: Phalacrocoracidae						
114	*Phalacrocorax carbo* (Linnaeus, 1758)	Great Cormorant	S	R	0.00002	C
115	*Phalacrocorax fuscicollis* (Stephens, 1826)	Indian Cormorant	ALL	R	0.01224	C

PM—Pre Monsoon | M—Monsoon | W—Winter | S—Summer
^R—Resident | WM—Winter migrant | SM—Summer Migrant
* P_i value— species abundance/total abundance in the community
$ O—Omnivorous | C—Carnivorous | I—Insectivorous | IV—Invertivorous | M—Molluscivorous | H—Herbivorous | G—Granivorous | N—Nectarivorous | F—Frugivorous

Table 2. Species richness values (both month-wise and season-wise) of the birds recorded in the present study.

Seasons	Months	Species Richness Values	
		Month wise	Season wise
Summer	Mar	81	85
	Apr	69	
	May	67	
Monsoon	Jun	62	69
	Jul	58	
	Aug	61	
Post-monsoon	Sep	63	86
	Oct	66	
	Nov	82	
Winter	Dec	99	104
	Jan	96	
	Feb	85	

reported in 2000 (Nandi et al. 2004); Santragachi Lake of Howrah District, West Bengal (22 species) (Roy et al. 2011); and Bakreswar and Hinglo Reservoirs and Adra Saheb Bandh Lake (24 species) (Khan et al. 2016). Though Purulia is an arid district, local aquatic bodies, especially Saheb Bandh and Kansai River, support the avian groups that dependent on aquatic habitat. The species richness value for the avian species was highest in winter, which is due to the presence of a large number of migratory birds especially in local water bodies like Saheb Bandh.

The resultant data reveals the functional roles and resource utilization patterns in the local ecosystem of the town. The availability of food resources is directly dependent on the precipitation rate and as an arid district of West Bengal, Purulia is severely deprived of water. Therefore, scarcity of water acts as a limiting factor for the survival of avian groups and a lesser number of granivores, herbivores, frugivores, and nectarivores throughout the year justifies the fact (Fig. 4). Interestingly, omnivores were highest in number followed by insectivores which might also be due to extreme weather conditions (Fig. 4). There are evidence about the influence of landscape on local species richness (Gaston 2000; Lawton 2000; Daube et al. 2003; Hossain & Aditya 2016).

As urbanization and developmental activities may destroy or degrade the natural habitats of birds therefore, there are urgent needs for the conservation of local habitats, including wetlands and water bodies. Successful conservation of birds would require continuous monitoring by government authorities and awareness among local people.

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Image 1–60. Birds photographed during the study: 1—*Accipiter badius* | 2—*Milvus migrans* | 3—*Pernis ptilorhynchus* | 4—*Circus aeruginosus* | 5—*Dendrocygna javanica* | 6—*Netta rufina* | 7—*Nettapus coromandelianus* | 8—*Anas clypeata* | 9—*Spatula querquedula* | 10—*Mareca penelope* | 11—*Anas acuta* | 12—*Mareca strepera* | 13—*Aythya nyroca* | 14—*Cypsiurus balasiensis* | 15—*Apus affinis* | 16—*Upupa epops* | 17—*Ocyceros birostris* | 18—*Charadrius dubius* | 19—*Vanellus indicus* | 20—*Vanellus malabaricus* | 21—*Hydrophasianus chirurgus* | 22—*Metopidius indicus* | 23—*Actitis hypoleucos* | 24—*Gallinago gallinago* | 25—*Calidris temminckii* | 26—*Gelochelidon nilotica* | 27—*Anastomus oscitans* | 28—*Leptoptilos javanicus* | 29—*Columba livia* | 30—*Spilopelia chinensis* | 31—*Streptopelia decaocto* | 32—*Streptopelia tranquebarica* | 33—*Treron phoenicopterus* | 34—*Alcedo atthis* | 35—*Ceryle rudis* | 36—*Halcyon smyrnensis* | 37—*Coracias benghalensis* | 38—*Merops orientalis* | 39—*Coracina macei* | 40—*Centropus sinensis* | 41—*Centropus bengalensis* | 42—*Clamator jacobinus* | 43—*Hierococcyx varius* | 44—*Eudynamys scolopaceus* | 45—*Falco tinnunculus* | 46—*Francolinus pondicerianus* | 47—*Amaurornis phoenicurus* | 48—*Fulica atra* | 49—*Gallinula chloropus* | 50—*Porphyrio porphyrio* | 51—*Eremopterix griseus* | 52—*Orthotomus sutorius* | 53—*Prinia socialis* | 54—*Cisticola juncidis* | 55—*Corvus splendens* | 56—*Dendrocitta vagabunda* | 57—*Dicrurus macrocercus* | 58—*Dicrurus aeneus* | 59—*Euodice malabarica* | 60—*Lonchura punctulate* | All photographs © Swastik Mahato.

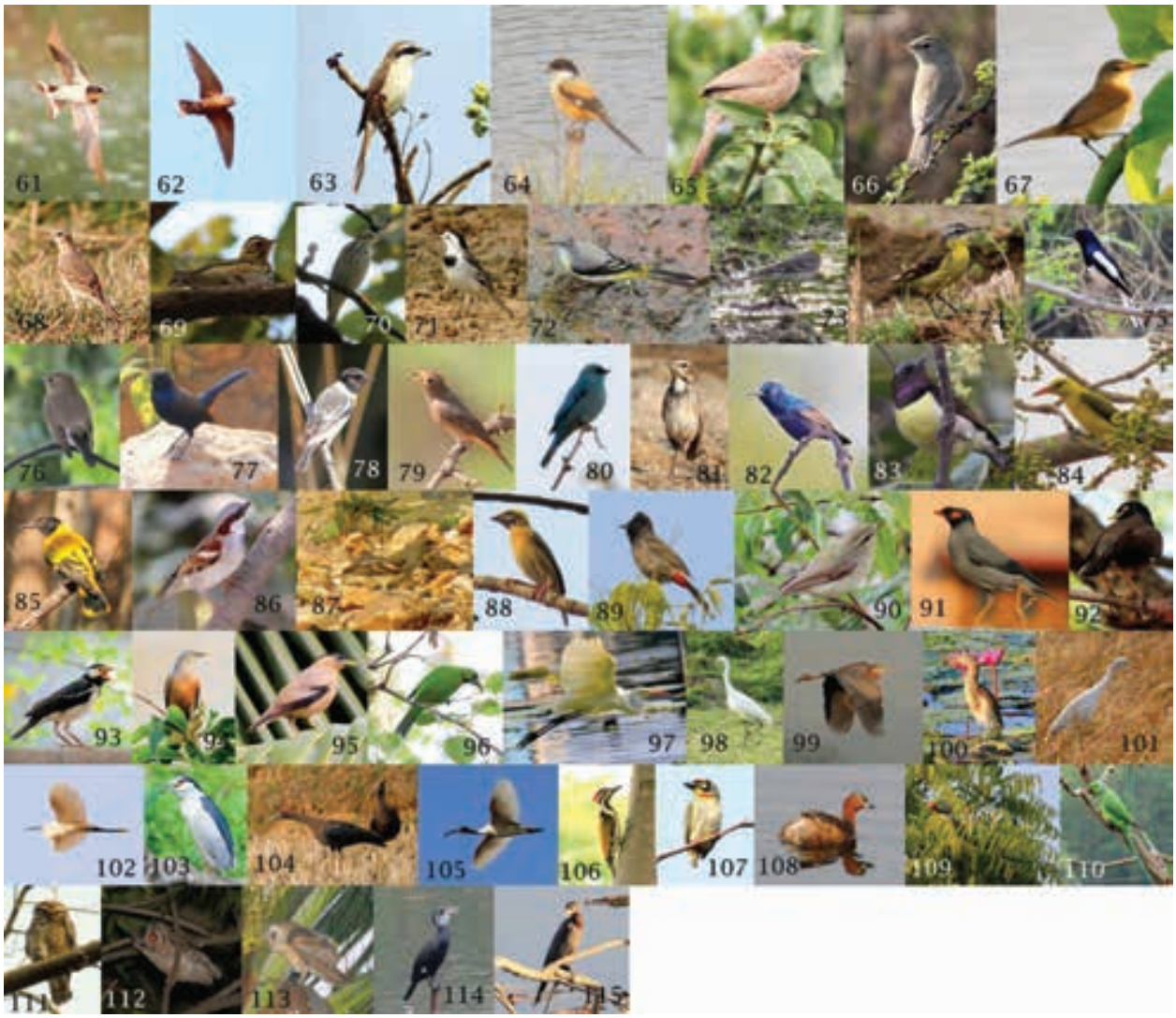

Image 61–115. Birds photographed during the study: 61—*Hirundo rustica* | 62—*Ptyonoprogne concolor* | 63—*Lanius cristatus* | 64—*Lanius schach* | 65—*Turdoides striata* | 66—*Iduna caligata* | 67—*Acrocephalus stentoreus* | 68—*Anthus rufulus* | 69—*Anthus hodgsoni* | 70—*Anthus trivialis* | 71—*Motacilla alba* | 72—*Motacilla cinerea* | 73—*Motacilla citreola* | 74—*Motacilla flava* | 75—*Copsychus saularis* | 76—*Ficedula albicilla* | 77—*Saxicoloides fulicatus* | 78—*Saxicola maurus* | 79—*Phoenicurus ochruros* | 80—*Eumyias thalassinus* | 81—*Luscinia svecica* | 82—*Cinnyris asiaticus* | 83—*Leptocoma zeylonica* | 84—*Oriolus kundoo* | 85—*Oriolus xanthornus* | 86—*Passer domesticus* | 87—*Gymnoris xanthocollis* | 88—*Ploceus philippinus* | 89—*Pycnonotus cafer* | 90—*Phylloscopus trochiloides* | 91—*Acridotheres ginginianus* | 92—*Acridotheres tristis* | 93—*Gracupica contra* | 94—*Sturnia malabarica* | 95—*Sturnia pagodarum* | 96—*Chloropsis jerdoni* | 97—*Ardea alba* | 98—*Ardea intermedia* | 99—*Ardea purpurea* | 100—*Ardeo lagrayii* | 101—*Bubulcus ibis* | 102—*Egretta garzetta* | 103—*Nycticorax nycticorax* | 104—*Pseudibis papillosa* | 105—*Threskiornis melanocephalus* | 106—*Dinopium benghalense* | 107—*Psilopogon haemacephalus* | 108—*Tachybaptus ruficollis* | 109—Psittacula eupatria | 110—*Psittacula krameri* | 111—*Athene brama* | 112—*Bubo bengalensis* | 113—*Tyto alba* | 114—*Phalacrocorax carbo* | 115—*Phalacrocorax fuscicollis* | All photographs © Swastik Mahato.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17918–17929
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6319.13.3.17918-17929
#6319 | Received 21 June 2020 | Final received 12 January 2021 | Finally accepted 19 March 2021
PLATINUM OPEN ACCESS
COMMUNICATION

An annotated checklist of amphibians in and around Dampa Tiger Reserve, Mizoram, India

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Abstract: Amphibians are an integral part of the ecosystem and act as an ecological indicator. As several species are added to the list of threatened species every year due to loss of habitat, it is important to understand the role of unmanaged landscape for sustenance of amphibian diversity. In this study, 28 amphibian species were recorded from different modified habitat including 19 new records for Dampa Tiger Reserve (DTR) and its surrounding areas. Further, six species, *Amolops indoburmanensis, Limnonectes khasianus, Microhyla mukhlesuri, M. mymensinghensis, Raorchestes rezakhani*, and *Sylvirana lacrima* are new distribution records for the state of Mizoram and out of these, two species, *Raorchestes rezakhani* and *Sylvirana lacrima*, are new country records for India. Amongst the recorded species, four species are Data Deficient, two Vulnerable, 14 Least Concern, and eight species are not assessed as per the IUCN Red List. Within the core and buffer areas of DTR, we found that natural perennial stream, puddles, canals, natural ponds, fish ponds, roadside, primary forest, secondary forest, paddy fields, and human settlement areas are excellent microhabitats for amphibian population and need to be conserved for their rich ecological niches.

Keywords: Conservation, microhabitat, protected area, *Raorchestes rezakhani,* recovery, secondary forest, *Sylvirana lacrima.*

Editor: Neelesh Dahanukar, Indian Institute of Science Education and Research, Pune, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Decemson, Ht., S. Gouda, Lalbiakzuala, Lalmuansanga, G.Z. Hmar, M. Vabeiryureilai & H.T. Lalremsanga (2021). An annotated checklist of amphibians in and around Dampa Tiger Reserve, Mizoram, India. *Journal of Threatened Taxa* 13(3): 17918–17929. https://doi.org/10.11609/jott.6319.13.3.17918-17929

Funding: The work was funded by the National Mission on Himalayan Studies (NMHS), with the sanction letter no. GBPNI/NMHS-2017/MG-221/5561 and NER-BPMC (North Eastern Region–Biotechnology Program Management Cell), Department of Biotechnology (DBT), Govt. of India, DBT-NER/AAB/64/2017.

Competing interests: The authors declare no competing interests.

Author details: See end of this article.

Author contribution: Ht. Decemson has led the field work, sample collection, initiate the manuscript writing and took some photographs. Sushanto Gouda has compiled the manuscript, designed the study area map and communicated the manuscript. Lalbiakzuala assist in the field work, contribute in the manuscript design and did molecular analysis for the collected samples. Lalmuansanga assist in the field work, sample collection and examination of the collected samples. Gospel Zothanmawia Hmar assist in the field work, sample collection and help in the manuscript editing. Mathipi Vabeiryureilai has assisted in the field work, sample collection and perform molecular identification for the collected samples. He also contributed in the manuscript write-up. H.T. Lalremsangais supervised the field work, sample collection, taken important photographs, did identification, provided valuable inputs and made necessary correction to the manuscript.

Acknowledgements: We thank the chief wildlife warden, Department of Environment, Forest and Climate Change, Government of Mizoram for the permission of herpetofauna collections in Miroram (Memo No: A.33011/2/99-CWLW/225). We acknowledge the National Mission for Himalayan Studies (NMHS) Uttarakhand (GBPNI/NMHS-2017/MG-22) and Department of Biotechnology (DBT), government of India, New Delhi, for providing financial assistance for laboratory facilities under NER-BPMC (North Eastern Region- Biotechnology Programme Management Cell) number DBT-NER/AAB/64/2017. We also appreciate the forest staff of Dampa Tiger Reserve for their help and cooperation during the course of field work.

INTRODUCTION

Change in matured forest lands into modified landscape through agriculture and other human activities had resulted in severe loss of biodiversity. Herpetofauna that contributes for over 48% of the terrestrial vertebrates is one of the most threatened groups of animals due to habitat loss, environmental pollution, international trade, and agroforestry (Palacios et al. 2013; Jayakumar & Nameer 2018; Prasad et al. 2018). As per IUCN, of the 8,126 described amphibian species, about 2,202 amphibians are categorized as threatened species (Frost 2020). In the past 20 years, the number of Critically Endangered species has also increased from 25 in the year 2000 to an alarming 587 species by 2020 (IUCN 2020). Dampa Tiger Reserve (DTR) in Mizoram, northeastern India, is a biodiversity hotspot that falls within the Indo-Burma region, and is also greatly affected from shifting cultivation and other anthropogenic activities (Pawar et al. 2004). About 80% of the State's population practices slash and burn method of agriculture that are highly dependent on forest resources, resulting in clearing of large areas of matured forest lands every year (Sati & Rinawma 2014). While most researchers have mostly emphasized on the conservation of faunal diversity in protected and matured forest, the importance of secondary or modified habitats has gained recognized in recent times (Dunn 2004; Teegalapalli et al. 2009; Mandal & Raman 2016; Vega-Pérez et al. 2019). Secondary forest types such as suburbia remnant forests, riverbanks, plantation sites, abandoned crop fields, and home gardens are reported to serve as an important refuges and breeding grounds for variety of amphibian fauna (Dunn 2004; Banville & Bateman 2012; Nowakowski et al. 2017; Prasad et al. 2018). Only a few studies on amphibians diversity has been reported from DTR that include amphibian survey by Pawar & Birand (2001), where the presence of 18 species were reported from different habitats like mature and secondary forest, open forest and even plantation sites. Recently, occurrences of Leptobrachella tamdil and Hoplobatrachus litoralis in DTR were reported by Vanlalsiammawii et al. (2020) and Kundu et al. (2020), respectively.

Thus, further studies that focus on the distribution, ecology and other quantitative aspects of amphibians are important to understand the fluctuations in ecosystem functioning and prioritize areas for conservation (Myers et al. 2000). Considering such rich and untamed amphibian diversity and paucity of research in the region, it is important to understand and evaluate the amphibian diversity in the modified ecosystems around the reserve.

MATERIALS AND METHODS

Study area

The study was carried out in the modified or secondary forested areas around Dampa Tiger Reserve, Mizoram, India. DTR is situated between 23.324–23.413 °N & 92.131–92.272 °E and encompasses a core area of 500km^2 and a buffer zone of 448km^2 (Figure 1). DTR consists of undulating and medium hills and slopes of mostly bamboo forest. Flat mainlands and patches of grasslands with lofty and evergreen run in parallel along the rivers (Pawar & Birand 2001). The climatic condition in DTR ranges 10–35 °C and receives an annual rainfall ranging 2,000–2,500 mm between the months of May to August (Pawar & Birand 2001). The area remains mostly moist due to presence of several small perennial streams thus forming an ideal habitat for biological assemblages for different groups of species. The region has a rich and diverse faunal diversity including Malayan Sun Bear, Clouded Leopard, Marbled Cat, Golden Cat, Hoolock Gibbon, Phayre's Leaf Monkey, King Cobra, and Burmese Python (Gouda et al. 2016; Singh & Macdonald 2017; Gouda et al. 2020a). Previous studies on the herpetofauna in DTR include works of Pawar & Birand (2001), Pawar et al. (2004), Lalrinchhana & Solanki (2015), and Vanlalsiammawii et al. (2020). Locals around DTR are mostly forest dwellers and are dependent on the available forest resources besides engaging in slash and burn practice of agriculture (Solanki et al. 2016).

Methods

Multiple approaches including visual encounter surveys (VES), acoustic surveys, drift fences, and pitfall traps were used for determination of amphibian diversity in different gradients of fallow forest lands along DTR. The study was carried out from September 2018 to July 2020 in three different seasons repeatedly. VES were carried out during early morning hours (06.30–10.00 h) and at night (18.00–24.00 h) for an average of five days each week using torch lights. Apart from passive observation, active searches were carried out in leaf litter, perennial streams, rocky outcrops, under rocks, peeling barks, abandoned crop fields, gooseberry, plantations (oil palm, rubber, mixed farms, etc.), and temporary rain puddles (Banville & Bateman 2012; Prasad et al. 2018). Opportunistic observations like road kills, canals along roadside and other areas were also noted during the survey. Identification of species

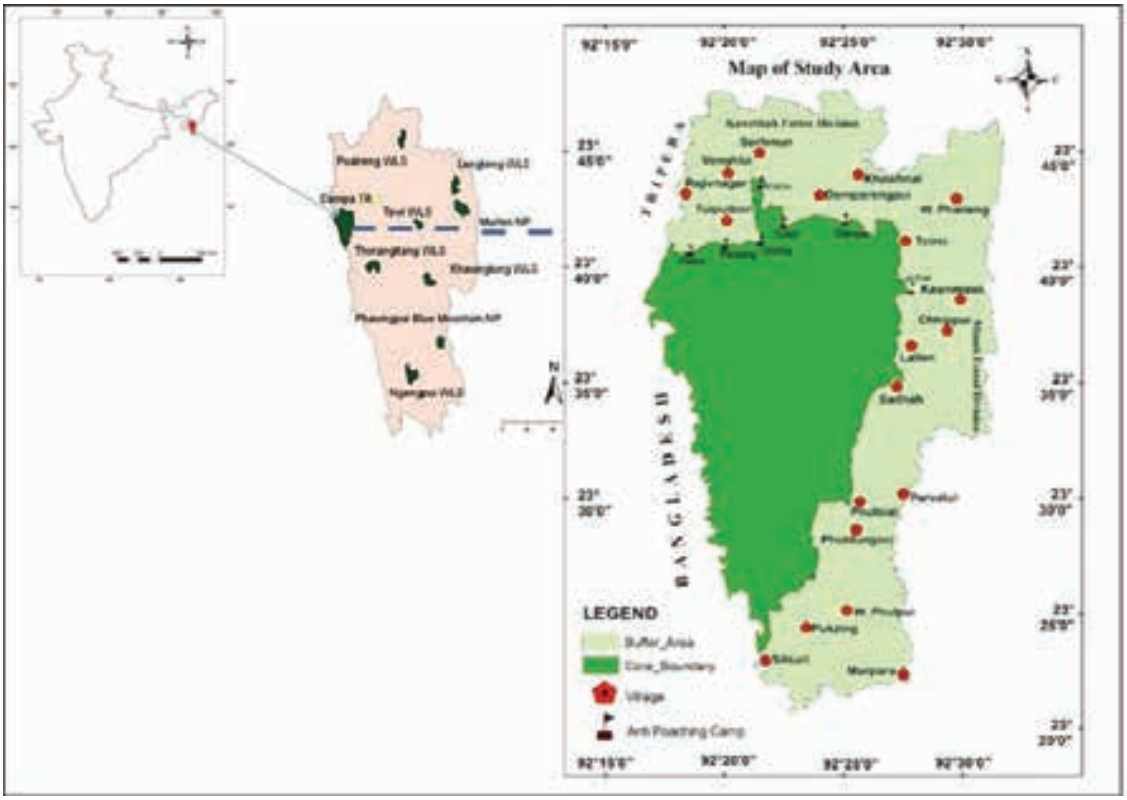

Figure 1. Representation of Dampa Tiger Reserve and its surrounding areas.

was made through reference catalogs available at the Departmental Museum of Zoology, Mizoram University and from literature (Boulenger 1890, 1920; Chanda 2002; Ahmed et al. 2009). Each location was covered on foot and individual species when encountered were photographed in their natural habitats wherever possible and GPS readings were recorded (Garmin etrex 10). Most of the collected specimens were released back in their natural habitat after examining and measurement. The species global distribution ranges are given according to Frost (2020).

For delimiting the identification of cryptic species, molecular approach was employed in which genomic DNA was extracted from the liver tissues of *Sylvirana lacrima* (MZMU 1632), *Raorchestes rezakhani* (MZMU 1785), *Microhyla berdmorei* (MZMU 1824), *Microhyla mukhlesuri* (MZMU 1766), *Microhyla mymensinghensis* (MZMU 1747), *Fejervarya multistriata* (MZMU 1360), and *Amolops indoburmanensis* (MZMU 1374) using DNeasy (Qiagen™) blood and tissue kits with the protocol given by the manufacturer. The fragment of mitochondrial 16S rRNA marker gene was amplified using forward primer L02510 (Palumbi 1996) and reverse primer H3056 (Rassmann 1997) in a 25µl volume following standard polymerase chain reactions (PCR) with standard thermal profiles for each primer pairs. Samples were sequenced in both directions using Sanger's dideoxy method on a sequencer at Agrigenome Labs Pvt. Ltd., Kochin, India. The chromatograms of the partial 16S rRNA sequences were screened through nucleotide BLAST (https://blast.ncbi.nlm.nih.gov/) and ORF finder (https://www.ncbi.nlm.nih.gov/orffinder/), the generated sequences were deposited in the GenBank repository and acquired the accession numbers (MW440531; MW165448; MW165451; MW165454; MW165457; MT627444; MT627446). Our sample sequences and of the closely related taxa downloaded from GenBank database were aligned by using Muscle algorithm in MEGA 7 (Kumar et al. 2016), the uncorrected p-distances were calculated using MEGA 7 (Kumar et al. 2016).

RESULTS

In the study, 28 species from seven families and 24 genera (Tables 1,2) were recorded from various modified forest patches in the vicinity of DTR (Images 1,2,3,4; Figure 2). This study reported 19 new distribution records from DTR (Table 1). Amongst the 28 documented species, four species are categorized as Data Deficient,

two as Vulnerable, 14 as Least Concern and eight species as not assessed as per IUCN Red List. Two species *i.e. Raorchestes rezakhani* and *Sylvirana lacrima* are first country records. A brief account of species recorded and their microhabitats are discussed here:

Species accounts

A. Order Anura

I. Family Bufonidae Gray, 1825

1. Indian Common Toad *Duttaphrynus melanostictus* (Schneider, 1799) (Image 1a)

It was the most commonly available toad recorded around Dampa Tiger Reserve (DTR). The species was sighted mostly at noon (12.16h) and dawn (18.02h) on the roadside and canals in an open forest of the fringe villages of Teirei and Damparengpui (260–430 m). Head broader than long; distinct angular dark ridges on head with tympanum large and distinctly clear; toes blunt, half webbed. Tip of warts and ridges are dark brown to black. It is distributed throughout south and southeastern Asia. n= 3 (two females and one male), SVL (Snout-vent length): 84–96 mm.

I. Family Dicroglossidae Anderson, 1871

1. Paddy Frog *Fejervarya multistriata* (Hallowell, 1861) (Image 1b)

An amplecting pair was recorded from muddy spot at Teirei Village at elevation 262m close to human settlement at 19.08h on 27 July 2019. Head triangular in dorsal view, nostrils closer to snout tip, males with characteristic laterally dark, medially pale colored throat, and vertebral line on dorsum. Distribution ranges from China, Hong Kong, Myanmar, India, Taiwan, Laos, Vietnam, and Thailand. The species is a new record for DTR. n= 2, SVL: 38.65mm (male) and 43.10mm (female). Genetic sequence of our specimen (MT627446) is similar to the sequences sampled from China (AB354241) and Japan (AB354239) for the species *Fejervarya multistriata* available in GenBank database showing uncorrected p-distances of 0.000 and 0.002 with our sample, respectively.

2. Bangladeshi Cricket Frog *Minervarya asmati* (Howlader, 2011) (Image 1c)

The species was collected from paddy field near Teirei Forest village, DTR at 19.30h on 26 August 2019. Head large and triangular, longer than wide, hind limbs relatively long, line on both sides of belly, smooth skin with minute warts or folds, fingers free of webbing, toes not fully webbed. Distribution ranges in Mizoram, India and Bangladesh. It is a new record for DTR. n= 3 (two males and one female), SVL: 29–33 mm.

3. Bangladesh Skittering Frog *Euphlyctis kalasgramensis* Howlader, Nair, Gopalan & Merilä, 2015 (Image 1d)

It is common and observed in all natural and constructed water bodies in the low lying surrounding the Reserve during early morning hours (08.00–10.00 h). An adult female was collected from a fish pond near Teirei Stream at an elevation of 248m. Skin color varies from grey to brownish. Head slightly broader, snout long and pointed; nostrils equidistant to eye. Fingers and toes pointed; toes fully webbed. It has a range of distribution throughout Bangladesh, India (Mizoram and western Punjab), and Pakistan. n= 1 (adult female), SVL: 64mm.

4. Indian Bull Frog *Hoplobatrachus tigerinus* (Daudin, 1802) (Image 1e)

The species was collected from a low lying area of Sunhlului in Damparengpui during the night survey (21.58h) on 20 May 2019. Skin is creamy or yellow colored with mid and dorsolateral lines from tip of the snout to posterior end. Found in low to moderate elevated areas in Afghanistan, Bangladesh, Nepal, India, and Pakistan. n= 1 (male), SVL: 129mm.

5. Coastal Bull Frog *Hoplobatrachus litoralis* Hasan, Kuramoto, Islam, Alam, Khan & Sumida, 2012 (Image 1f)

Recorded from Tuidamlui (230m) at 20.00h on 12 July 2020, the species is commonly available around DTR. Distinct black margins in the upper arm, dorsum dark gray with many large black spots. Dorsal ground colour varies from yellowish to dark brown with many dark brown to black spots. Global distribution includes Bangladesh, India, and Myanmar. n= 1 (male), SVL: 122mm.

6. Northern Trickle Frog *Ingerana borealis* (Annandale, 1912) (Image 1g)

Fairly common in northeastern India, a single individual of this species was collected from a boulder of Selinglui Stream, around DTR at an elevation of 244m during night survey (18.26h) on 19 November 2019. It is a seasonal breeder, i.e., during April to August. Small-sized frog; head small and triangular; snout bluntly rounded; tympanum rounded; legs and fingers free and toes half webbed. Dorsum and flanks are reticulated and with small net-like ridges and tiny glandular warts. Distributions are in China, Bhutan, Nepal, India, Bangladesh, and Myanmar. It is a new record for DTR. n= 1 (male), SVL: 29mm.

Table 1. Checklist of amphibian species recorded from different habitats in and around DTR during 2018–2020. The frog species with asterisk (*), hash (#), and plus (+) are new records from DTR, Mizoram, and India, respectively.

Family	Common name	Species	IUCN RL status
Bufonidae	Common Asian Toad	*Duttaphrynus melanostictus*	Least Concern
Dicroglossidae	Paddy Frog	*Fajervarya multistriata**	Data Deficient
	Bangladeshi Cricket Frog	*Minervarya asmati**	Least Concern
	Bangladesh Skittering Frog	*Euphlyctis kalasgramensis**	Least Concern
	Indian Bull Frog	*Hoplobatrachus tigerinus*	Least Concern
	Coastal Bull Frog	*Hoplobatrachus litoralis*	Not assessed
	Northern Trickle Frog	*Ingerana borealis**	Vulnerable
	Khasi Wart Frog	*Limnonectes khasianus*#*	Data Deficient
Megophryidae	Red-eyed Frog	*Leptobrachium smithi*	Least Concern
	Tamdil Leaf-litter Frog	*Leptobrachella tamdil*	Not assessed
	Beautiful Pygmy Frog	*Megophrys major**	Least Concern
	Serchhip Horned Frog	*Megophrys serchhipii**	Data Deficient
Microhylidae	Mukhlesur's Narrow-mouthed Frog	*Microhyla mukhlesuri**	Not assessed
	Mymensingh Narrow-mouthed Frog	*Microhyla mymensinghensis*#*	Not assessed
	Berdmore's Narrow-mouthed Frog	*Microhyla berdmorei**	Least Concern
	Painted Balloon Frog	*Kuloula pulchra*	Least Concern
Ranidae	Indo-Burma Torrent Frog	*Amolops indoburmanensis*#*	Not assessed
	Pointed-nose Frog	*Clinotarsus alticola**	Least Concern
	Indo-Burma Stream Frog	*Sylvirana lacrima*#+*	Least Concern
	Assam Forest Frog	*Hydrophylax leptoglossa*	Least Concern
	Green-backed Stream Frog	*Odorrana chloronota**	Least Concern
	Khare's Gliding Frog	*Pterorana khare**	Vulnerable
Rhacophoridae	Common Tree Frog	*Polypedates teraiensis**	Not assessed
	Annandale's Pygmy Tree Frog	*Chirixalus simus**	Least Concern
	Giant Tree Frog	*Zhangixalus smaragdinus*	Not assessed
	Twin-spotted Tree Frog	*Rhacophorus bipunctatus*	Least Concern
	Reza Khan's Bush Frog	*Raorchestes rezakhani*#+*	Not assessed
Ichthyophidae	Manipur Moustached Ichthyophis	*Ichthyophis moustakius**	Data Deficient

Table 2. Amphibian family, species, and genera accounted from different habitats around DTR during 2018–2020.

Family	Genera	Species
Ichthyophidae	1	**1**
Bufonidae	1	**1**
Dicroglossidae	6	**7**
Megophryidae	3	**4**
Microhylidae	2	**4**
Ranidae	6	**6**
Rhacophoridae	5	**5**
Total	24	**28**

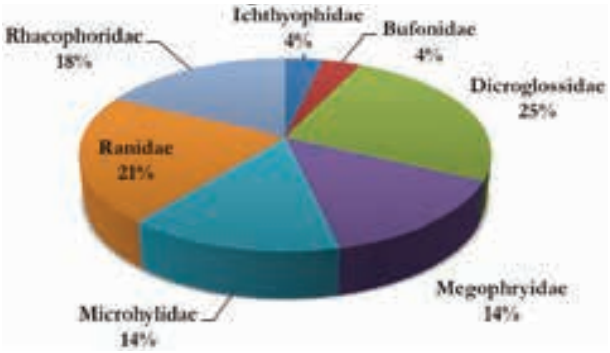

Figure 2. Family composition of amphibian species recorded in the study.

Image 1. Frog species with asterisk (*), hash (#), and plus (+) are new records for DTR, Mizoram, and India, respectively: a—*Duttaphrynus melanostictus* | b—*Fejervarya multistriata | c—*Minervarya asmati** | d—*Euphlyctis kalasgramensis* | e—*Hoplobatrachus tigerinus* | f—*Hoplobatrachus litoralis** | g—*Ingerana borealis** | h—*Limnonectes khasianus*#* | i—*Leptobrachium smithi* | Photographs: a,d,e,f,h,i © H.T. Lalremsanga; b,c,g © Ht. Decemson.**

7. Khasi Wart Frog *Limnonectes khasianus* (Anderson, 1871) (Image 1h)

A single female individual Khasi Wart Frog was recorded from a stream along the reserve boundary at Khawhthlabung Fall at Teirei Stream near Lallen Village (17.15h) on 11 July 2018. They are mostly of medium-sized, short and thick body. Eyes are large and prominent. Skin smooth throughout, no trace of tubercles. This is a new record for the state of Mizoram. The species is endemic to northeastern states of Assam, Meghalaya, and Mizoram. n= 1 (female), SVL: 35.61mm.

I. **Family Megophryidae Bonaparte, 1850**

1. Red-eyed Frog *Leptobrachium smithi* Matsui, Nabhitabhata & Panha 1998 (Image 1i)

A male and female individual of the species were recorded from the secondary forested area near the Forest Guest House of Teirei Forest complex at an elevation 240m during noon time (11.54h) on 24 April 2018. Head is broader and long; nostrils nearer to tip of snout; eyes large; mouth wide; limbs slender and weak; fingers free; toes webbed; finger and toe tips blunt. Dorsum ash to black in colour with several black spots and markings. Distribution ranges include Thailand, Myanmar, Malaysia, Laos, India, and Bangladesh. n= 2, SVL: 42mm (male) and 61mm (female).

2. Tamdil Leaf-litter Frog *Leptobrachella tamdil* (Sengupta, Sailo, Lalremsanga, Das & Das 2010) (Image 2a)

The record of this species in DTR is based on Vanlalsiamawii et al. (2020). n= 1 (male), SVL: 31mm.

3. Beautiful Pygmy Frog *Megophrys major* Boulenger, 1908 (Image 2b)

A male pygmy frog was recorded around fallen dried bamboo forest around Khawhthlabung fall at Teirei Stream near Lallen Village at 19.18h on 10 June 2018. Head broader than long; triangular, eyes large, prominent, jutting out above head; snout broadly pointed; nostril

closer to eye. Dorsum dark brown in colour. Distribution ranges include India, Myanmar, Thailand, Laos, Vietnam, and Cambodia. It is a new report for DTR. n= 1 (male), SVL: 79mm.

4. Serchhip Horned Frog *Megophrys serchhipii* (Mathew & Sen, 2007) (Image 2c)

A female narrowed-mouth frog was recorded from Seling Stream at an elevation of 244m during the night survey (21.33h) on 22 August 2019. Head moderately large, distinct oval tympanum, snout rounded in dorsal view, nostril oval. Skin of dorsal surfaces of head, body and limbs, smooth to rugose with small weak granular tubercles. V-shaped mark on head covering the middle of the eyelids. It is native to the states of Meghalaya, Mizoram, and Tripura in India. Also found in southeastern Bangladesh and southwestern Myanmar. This is also a new report for DTR. n= 1 (female), SVL: 42mm.

II. **Family Microhylidae Günther, 1858**

1. **Mukhlesur's Narrow-mouthed Frog *Microhyla mukhlesuri* Hasan, Islam, Kuramoto, Kurabayashi & Sumida, 2014 (Image 2d)**

The species was identified from shallow perennial stream, beneath submerged leaf debris situated near roadside at Zodin locality of Damparengpui Village at elevation 407m at 19.33h on 16 February 2020. Broad head and pointed; snout obtuse, and broadly rounded; tongue elliptical; inter orbital width broader than eye diameter; tympanum invisible. Limbs moderate, tibia-tarsal articulation up to eye level; fingers free; toes webbed at the base; tips of finger and toes not swollen; subarticular tubercles distinct; an inverse U-shaped mark on the anus: a distinct X-shaped marking on the dorsum. Skin smooth, brownish or grayish. The species is distributed across Bangladesh, Thailand, Laos, Vietnam, and northeastern India. n= 1 (male), SVL: 18.5mm. Genetic sequence of our specimen (MW165451) is similar to the GenBank database sequences of *Microhyla mukhlesuri* sampled from Mizoram, India (MH549575), Bangladesh (MN534585), and Myanmar (KC179995) with the uncorrected p-distances of 0.000, 0.000, and 0.021 from our sample, respectively.

2. **Mymensingh Narrow-mouth Frog *Microhyla mymensinghensis* Hasan, Islam, Kuramoto, Kurabayashi & Sumida, 2014 (Image 2e)**

A female individual was collected from a grass in the backyard of ranger officer's quarter at Teirei range at elevation 261m at 21.45h on 10 July 2020. Broad head and pointed; snout truncate; a crescent-shaped marking on the anus an X-shaped marking on the dorsum; tympanum hidden. Limbs moderate, tibia-tarsal articulation up to the level from the eye to the tip of the snout; fingers free; toes webbed at the base; skin smooth, reddish or grayish; inverted crescent mark around anus. The species is distributed across central and northeastern parts of Bangladesh and Wet Bengal, Assam, and Nagaland in India. n= 1 (female), SVL: 20.8mm. Genetic sequence of our specimen (MW165448) is similar to the GenBank database sequences of *Microhyla mymensinghensis* sampled from Tripura, India (MH549589), Assam, India (MH549576), Manipur, India (MH549580), Nagaland, India (MH549584), and Bangladesh (MK635493); showing the uncorrected p-distances of 0.002, 0.004, 0.004, 0.016, and 0.004 with our sample, respectively.

3. **Berdmore's Narrow Mouthed Frog *Microhyla berdmorei* (Blyth, 1856) (Image 2f)**

It was sighted along the puddle at road side of Damparengpui Village at elevation point 407m in evening survey (19.27h) on 18 February 2020. A pointed and broad head; snout obtusely pointed; tympanum hidden; bronze or pinkish above; a dark slightly light blue edged, large mid dorsal spot on back. Distribution ranges in Arunachal Pradesh, Assam, Manipur, Mizoram, Tripura, & Meghalaya (India), northern Bangladesh, Yunnan (China), Myanmar, Thailand, through Laos, most of Vietnam north of the Mekong River, Cambodia south to peninsular Malaysia, Sumatra, and Borneo (Indonesia). This is also a new report for DTR. n= 5 (four male and one female), SVL: 32–36 mm. Genetic sequence of our specimen (MW165457) is similar to the GenBank database sequences of *Microhyla berdmorei* sampled from Assam, India (MH807388), and Bangladesh (MN534602) with an uncorrected p-distance of 0.004 with our sample.

4. **Painted Balloon Frog *Kaloula pulchra* Gray, 1831 (Image 2g)**

The species was recorded from two separate locations. The SVL of the female frog from a pot-hole on the boulder near Teirei IB guest house (elevation 241m at 20.28h on 20 April 2020) measured 82mm, while the other individuals were collected from a burrow in the vicinity of Sesihlui (764m elevation at 14.49h on 9 April 2019) measured 86mm (female) and 79mm (male). Head broader than long, snout short round and nostrils closer to tip of snout. Dorsum is dark brown with bright orange broad band extending from tip to either side of body. It is common in India, Bangladesh, Myanmar, Thailand, China, Singapore, Sumatra, Borneo, and is introduced into the Philippines.

Image 2. Frog species with asterisk (*), hash (#), and plus (+) are new records for DTR, Mizoram, and India, respectively: a—*Leptobrachella tamdil* | b—*Megophrys major | c—*Megophrys serchhipii** | d—*Microhyla mukhlesuri** | e—*Microhyla mymengsinghensis*#* | f—*Microhyla berdmorei** | g—*Kuloula pulchra* | h—*Amolops indoburmanensis*#* | i—*Clinotarsus alticola** | Photographs: a,b,c,d,e,f,h,i © H.T. Lalremsanga; g © Ht. Decemson.**

IV. Family Ranidae

1. Indo-Burma Torrent Frog *Amolops indoburmanensis* Dever, Fuiten, Konu & Wilkinson, 2012 (Image 2h)

A male Indo-Burma Torrent Frog was collected along the concrete wall of the forest guest house at Teirei Village at 20.44h on 8 June 2019. Three more individuals were collected from Dampa stream near Damparengpui Village at 19.00–20.00 h. It is a large-sized frog with a brown dorsum, scattered with dark brown sharp spots from snout to vent. Skin mid-dorsally smooth becoming tuberculated laterally. Large prominent discs present on tips of digits. It is reported from Myanmar in Chin State, Rakhine State, southern Sagaing Division, and western Bago Division, possibly into Manipur, India. It is a new report for DTR as well as Mizoram. n= 4 (two males and two females), SVL: 68–92 mm. Genetic sequence of our specimen (MT627444) is similar to the GenBank database sequence of *Amolops indoburmanensis* sampled from Mizoram, India (MH059579) with an uncorrected p-distance of 0.000 between them.

2. Pointed-nosed Frog *Clinotarsus alticola* (Boulenger, 1882) (Image 2i)

A female species was found perching on the rock in a riparian stream close to the secondary forest between Khawhnai and Teirei villages at around 17.26h on 19 November 2019. Head longer; skin smooth; tympanic fold ending in glandules at corner of mouth. Males are green and female are orange in colour. Distribution ranges include Bangladesh and India. n= 1 (female), SVL: 68mm.

3. Indo-Burma Stream Frog *Sylvirana lacrima* Sheridan & Stuart, 2018 (Image 3a)

The species was recorded in early hours at 05.30h on 19 November 2019 from the Selinglui flowing through Tuicharlui to core areas of DTR. Another individual of the same species was recorded at 18.32h in leaf litter of the bamboo forest floor outside the reserve. Broader

head, an oblique, triangular or tear drop shaped marking slightly posterior to the tympanum. Skin was finely granular above and smooth below with thin dark stripe just ventral dorso-lateral glandular fold prominent. The postaxial side of toe IV webbed to base of disc. This species is known from Chin and Mandalay states in western Myanmar. The species is a new country report. n= 2, SVL: 42mm (male) and 68mm (female). Earlier presumed to be *Amnirana* cf. *nicobariensis*; upon molecular analysis the species was found to be actually *Sylvirana lacrima.* The data on molecular analysis are attached as supplementary files. Genetic sequence of our specimen (MW440531) is similar to the sequences (MG606590; MG606592; MG935996) for the species *Sylvirana lacrima* available in GenBank database by the uncorrected p-distances of 0.000–0.009 with our sample.

4. Assam Forest Frog *Hydrophylax leptoglossa* (Cope, 1868) (Image 2b)

We recorded two individuals of this species at different occasions at 09.35h from human settlement area of Damparengpui Village at 403m and another individual at 12.20h on 1 December 2019 near Sunhlului Stream along foot trails with elevation of 689m. Head was long; nostrils lateral, nearer to tip of snout, tympanum almost as large as eye, rictal gland present at the base of forelimb, hind limbs moderate, toes 2/3rd webbed. Males have external vocal sacs. Distribution ranges in Bangladesh, India, Myanmar, and Thailand. n= 2 (two females), SVL: 54–61 mm.

5. Green-backed Stream Frog *Odorrana chloronota* (Günther, 1876) (Image 3c)

We recorded the species near an anti-poaching camp situated in the buffer zone of DTR at 17.04h on 21 September 2018 at an elevation of 242m. Head broader than long, much depressed. Dorsum green, with a row of large black spots on the mid-dorsum. A prominent white streak is present on both sides of upper jaw. Glandular fold originates from posterior corner of eyes to the shoulder, which is followed by a glandule. Tympanum brown with white circular rim. Originally described as '*Polypedates chloronotus*', the species distribution ranges from Darjeeling region of West Bengal, Sikkim and mountains of northeastern India (Assam, Meghalaya, and Mizoram), through Myanmar to southern China and southern Vietnam. It is a new report for DTR. n= 1 (male), SVL: 48mm.

6. Khare's Gliding Frog *Pterorana khare* Kyasetuo & Khare, 1986 (Image 3d)

A male individual (SVL: 65.8mm) was collected from Khawhthlabung at Teirei Stream near Lallen Village at 16.30h on 20 September 2018 at an elevation of 547m. Head broader than long; nostrils laterally placed equidistant to eyes and tip of snout; tympanum distinct a dark band from corner of eye to shoulder along tympanic fold. Dorsum slate dark brown, ventrally white. Toes fully webbed. A lateral skin expanded from behind the tympanum up to the groin including thighs. Flap on the left measured 18mm width when stretched. The species is known from the northeastern states of India and Chin State of Myanmar. It is also a new record to DTR and a small population was observed in this section of stream.

V. Family Rhacophoridae Hoffman, 1932 (1858)

1. Common Tree Frog *Polypedates teraiensis* (Dubois, 1987) (Image 3e)

It was collected from the human settlement areas of Teirei Forest village at 16.40h on 24 September 2018 at an elevation of 253m. A large-sized frog, dorsal skin smooth, tips of fingers and toes with large discs, webbing moderate, dorsal color light brown with longitudinal brown lines, and has ossified cephalic skin on head. Distribution ranges are Nepal, India, Bangladesh, Myanmar, and China. It is a new record for DTR. n= 1 (female), SVL: 80mm.

2. Annandale's Pygmy Tree Frog *Chirixalus simus* Annandale, 1915 (Image 3f)

The species was observed near the forest guest house of Teirei forest at an elevation of 240m at 20.25h on 26 August 2019. A small tree frog, head are long; nostrils, closer to tip of snout; dorsum greyish to brownish; a dorsolateral white band on either side. Distributions are reported from India and Bangladesh. It is a new record for DTR. n= 1 (female), SVL: 23mm.

3. Giant Tree Frog *Zhangixalus smaragdinus* (Blyth, 1852) (Image 3g)

The species was collected from litter along the road edges with stagnant water at 12.49h on 3 April 2019 near Damparengpui Village at an elevation of 455m. Head broader than long; tympanum distinct, fingers webbed, discs prominent; dorsum, green; ventrally yellowish; dorsal skin smooth, ventral and lateral sides minutely granulated; toes fully webbed. It is distributed in India, Nepal, China, and Bangladesh. n= 1 (female), SVL: 93mm.

Image 3. Frog species with asterisk (*), hash (#), and plus (+) are new records for DTR, Mizoram, and India, respectively: a—*Sylvirana lacrima#+ | b—*Hydrophylax leptoglossa** | c—*Odorrana chloronota** | d—*Pterorana khare** | e—*Polypedates teraiensis** | f—*Chiromantis simus** | g—*Zhangixalus smaragdinus* | h—*Rhacophorus bipunctatus** | i—*Raorchestes rezakhani**#+ | j—*Ichthyophis moustakius** | Photographs: b,c,d,f,g,h,I,j © H.T. Lalremsanga; a,e © Ht. Decemson.**

4. Twin-spotted Tree Frog *Rhacophorus bipunctatus* Ahl, 1927 (Image 3h)

A female species was sighted which was resting on a leaf of *Licuala peltata* along the road leading to jhum fields at an elevation of 725m at around 11.58h on 1 December 2019. Head broader than long; nostril equidistant between the tip of snout and eye. The species distribution region is considered to be well documented from Bangladesh, China, Laos, Vietnam, Cambodia, Myanmar, Thailand, and India. Recently, the occurrence of the species in DTR was confirmed by Decemson et al. (2020). n= 1 (female), SVL: 59mm.

5. Reza Khan's Bush Frog *Raorchestes rezakhani* Al-Razi, Maria & Muzaffar, 2020 (Image 3i)

The female specimen (SVL: 19.5mm) was found from the bushes at the peak of Pathlawilunglentlang, near Damparengpui Village at ca. 18.00h on 7 July 2019 at an elevation of 578m. It is having a grayish-brown dorsum with "-("mark, less distinct bars on arms and legs; rounded snout, indistinct supratympanic fold and tympanum; pupil oval, horizontal; vomerine teeth absent; rounded discs on tips of digits; inner and outer metacarpal tubercles absent; metatarsal tubercles absent; belly pale white. Genetic sequence of our specimen (MW165454) is similar to the GenBank database sequences sampled from Bangladesh (MN072374; MN615902) by the uncorrected p-distance of 0.007 with our sample.

B. Order Gymnophiona

VI.Family Ichthyophidae Fitzinger, 1826

1. *Ichthyophis moustakius* Kamei, Wilkinson, Gower & Biju, 2009 (Image 3j)

A single *Ichthyophis moustakius* individual was collected from a roadside near the entry of the forest guest house, Teirei (241m) at 23.50h on 12 July 2020. The species identification is based on the original description by Kamei et al. (2009). Its known distribution range includes Aziuram, Nswanram, Nriangluang, Guwahati Metropolitan, and Bamgaizaeng in Tamenglong District, Manipur, and Sawleng Village in Aizawl District, Mizoram, in northeastern India. This is a new record for DTR. n= 1, dorsal annular groove: 275, head length: 11mm, head width: 9mm, SVL: 195mm, total length: 199mm.

DISCUSSION

In the study, 28 species were documented from different habitat types including streams, roadside, secondary forest, and human settlements (Image 5). While 19 species are new records from DTR and six species, *Amolops indoburmanensis, Limnonectes khasianus, Microhyla mukhlesuri, M. mymensinghensis, Raorchestes rezakhani*, and *Sylvirana lacrima* are new to the State's amphibian fauna and out of these, two species *Raorchestes rezakhani* and *Sylvirana lacrima* are new records for the country (Table 1). From the present study, we assumed that the report of *Euphlyctis cyanophlyctis, Limnonectes laticeps, L. limnocharis*, and *Raorchestes* (*Philautus*) *parvulus* by Pawar & Birand (2001) might possibly be *Euphlyctis kalasgramensis, L. khasianus, Minervarya asmati*, and *Raorchestes rezakhani*, respectively. Although Pawar & Birand (2001) reported *Megophrys parva* from this area, Mahony et al. (2020) recently removed *M. parva* from the Indian faunal list and reassigned it as *M. serchhipii.* This is also evidenced by our morphological and molecular analysis of the specimens collected from this area. We also suggested *Microhyla ornata* and *Odorrana* (*Rana*) *livida* reported by Pawar & Birand (2001) supposed to be *M. mukhlesuri* or *M. mymensinghensis* and *O. chloronota* in viewing their current distribution records and genetic data, respectively. The reports of the species *Rhacophorus bipunctatus* and *Microhyla berdmorei* based on secondary source of information by Pawar & Birand (2001) was confirmed through direct records in our study and are listed as new records to DTR. Also, the record of *Amolops marmoratus* and *A.* cf. *viridimaculatus* by Pawar & Birand (2001) are most likely to be *A. indoburmanensis* depending upon the morphological and molecular analysis from the present collection. *Polypedates leucomystax* cf. *sexvirgatus* which was previously reported in the area (Pawar & Birand 2001) is also supposed to be *P. teraiensis* based on the current distribution.

Most of the species were recorded from natural perennial streams flowing from the core region towards the buffer areas of DTR. The Teirei Forest Guest House situated at the edge of DTR is also an ideal microhabitat for amphibians as it is surrounded by the juxtaposition of primary and secondary forests comprising rubber and oil palm plantations, cultivation, riparian forest, paddy field, streams, and human settlements with a mixture of hilly and undulating terrain. Studies on amphibian recovery pattern by Pawar et al. (2004) and Dunn (2004) has found that amphibians tend to recover to their full strength between the first 10 years of their habitat alteration. They also reported that, there is no significant age determinacy along different gradient of habitat recovery, however, factors such as soil moisture content, organic matter content, and ground litter cover are positively correlated and crucial for recovery of amphibian and reptiles in a modified habitat. Many other researchers have also identified such modified areas as excellent habitat for small mammals, birds, and reptilian species (Dunn 2004; Pawar et al. 2004; Palacios et al. 2013; Mandal & Raman 2016; Vega-Pérez et al. 2019). DTR has a buffer area of about 448km^2, where over 22,000 people are residing and practice shifting or jhum cultivation. The jhum fields are often left fallow after harvesting, thereby creating a mosaic of microhabitats that attracts several forms of faunal diversity (Gouda et al. 2020b). As amphibians are an important link in the food chain in terrestrial and aquatic ecosystems, it is important to understand their

distribution in both modified and natural ecosystems for planning their long term conservation.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17930–17938
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6763.13.3.17930-17938
#6763 | Received 02 October 2020 | Final received 24 November 2020 | Finally accepted 20 March 2021
PLATINUM OPEN ACCESS
COMMUNICATION

Redescription of the bug *Aschistocoris brevicornis* (Heteroptera: Coreidae) and first report on its life history from northern Maharashtra, India

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Abstract: We redescribe *Aschistocoris brevicornis* (Dallas, 1852) from northern Maharashtra, India, a species belonging to the tribe Homoeocerini (Heteroptera: Coreidae: Coreinae). Here we have provided detailed, well-illustrated morphology, including the male genitalia, and notes on its bionomics for the first time.

Keywords: *Aschistocoris, Butea monosperma,* Coreinae, Homoeocerini, life history.

Editor: Anonymity requested.

Date of publication: 26 March 2021 (online & print)

Citation: Jadhav, D.R., R.R. Khairnar, B.V. Sarode, S.S. Boyane & H.V. Ghate (2021). Redescription of the bug *Aschistocoris brevicornis* (Heteroptera: Coreidae) and first report on its life history from northern Maharashtra, India. *Journal of Threatened Taxa* 13(3): 17930–17938. https://doi.org/10.11609/jott.6763.13.3.17930-17938

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author details: Jadhav and Khairnar are present MSc Zoology students while Sarode and Boyane are past students of this department. Boyane is now with ATREE (Bangalore) while Sarode is self-employed - both are actively looking at biodiversity of bugs. Jadhav and Khairnar are at present doing MSc project on aquatic insects of Dhule area. H.V Ghate is a retired college teacher pursuing taxonomical work.

Author contribution: Jadhav and Khairnar studied life history in Dhule area and recorded the details presented here. Sarode initiated this work when he collected a pair. Sarode and Boyane helped in dissection, photography and preparation of illustrations. Ghate wrote the manuscript with inputs from all co-authors.

Acknowledgements: We are indebted to Bill Dolling (U.K) for correcting and shaping this manuscript, especially the first part dealing with morphology, as well as for continuous support to HVG. Both Ms. Khairnar and Mr. Jadhav thank their families for supporting this work at home during this lockdown period; in addition Mr. Rajendra Khairnar (father) helped in field work. Staff at Department of Zoology, R.C. Patel Arts, Science & Commerce College, Dhule, provided some support to Mr. Jadhav and we gratefully acknowledge that. The authors are indebted to the authorities of Progressive Education Society and Modern College for facilities and encouragement.

INTRODUCTION

The family Coreidae includes relatively robust, elongate bodied bugs, some of which are among the largest of Heteroptera, however, there are also some slender and delicate species in this family (Schuh & Slater 1995). During an ongoing search for Heteroptera in Maharashtra, a pair of bugs collected in Shahada (District Nandurbar, Maharashtra State, July 2017), on Palash Tree *Butea monosperma* (Lam.) Taub. (Fabaceae: Papilionaceae), proved to be *Aschistocoris brevicornis*, providing the opportunity to describe and figure this "apparently rare" species in detail. Recent surveys initiated in nearby areas, namely Shirpur and Nizampur (District Dhule, Maharashtra State, June to November 2020), revealed breeding populations of this bug at these two localities. We could then observe mating, egg-laying, and nymphal development on *Butea,* both in natural as well as 'home laboratory' conditions.

Stål (1873) founded the genus *Aschistus* for the species described by Dallas (1852) as *Ornytus? brevicornis* from 'North Bengal'. Later *Aschistus brevicornis* was briefly redescribed and figured by Distant (1902) with the same locality data as presented by Dallas. Subsequently, Distant (1908) described two more species, *Aschistus nepalensis* from '[Nepal]: Benikhola and Bijdura; [India]: United Provinces, Naini Tal Districts' and *A. sulcatus* from [Myanmar]: 'Pegu, Palon.'

Bergroth (1909) proposed the nominal genus *Aschistocoris* as a replacement name for *Aschistus* Stål, preoccupied by *Aschistus* Förster, 1868 (in Hymenoptera, as stated by Bergroth 1909; original paper by Förster not seen), and described another species, *Aschistocoris bombaeus*, from a male specimen collected in 'Bombay', India.

Distant (1918) applied the genus name *Aschistocoris* to all four species but regarded *A. bombaeus* as possibly a variety of *A. brevicornis*; he also added a new locality for *A. brevicornis*: 'Central Prov.; Bhandara (on Dhak)' (now Bhandara District of Maharashtra State, India). Dhak is the local name of *Butea monosperma*. He also added 'N. India: Dehra Dun, Sabhawala' (Sabhawala is a village in Dehradun District, Uttarakhand State of India) to the locality data for *A. sulcatus*.

Ahmad & Perveen (1983) revised the genus *Aschistocoris* for the Oriental region and added two new species to the genus - *A. neonepalensis* from 'Nepal' and *A. schaeferi* from 'S. India: Pondicherry' (now Puducherry, a Union Territory on the eastern coast). They provided a key to the five species then included in the genus and discussed its relationship with *Anhomoeus* Hsiao, 1963. Perveen (1991) transferred both *A. nepalensis* and *A. sulcatus* to the genus *Anhomoeus*, leaving only *brevicornis, neonepalensis* and *schaeferi* in *Aschistocoris*, though the status of *A. bombaeus* remained unexamined. More & Ghate (2018) had discussed part of this issue earlier. All species of the genus *Aschistocoris,* as it is now constituted, are confined to India and Nepal.

In a recent paper, Biswas et al. (2014) reported this species from Raipur, Chhattisgarh State, India, and gave a brief diagnosis accompanied by a photograph of the dorsal habitus. Although they did not indicate the sex of their specimen it is apparent from the photograph that it is a female. Their photograph, however, does not show the median pale longitudinal line on the pronotum and scutellum that is present in our material and in the image of the female 'type' specimen of *A. brevicornis* available on the Coreoidea Species File website. We are unable to agree that the specimen in Biswas et al. (2014) belongs to this species and perhaps even to this genus. There are no other recent published reports of any species of *Aschistocoris* from India. Prabakar (2015) listed only *A. brevicornis* from India, citing the localities Madhya Pradesh and Sikkim; he made no mention of either *A. bombaeus* or *A. schaeferi,* the other two species known from India.

Here we redescribe *Aschistocoris brevicornis,* based on recently collected specimens from Maharashtra, with several illustrations. In addition, we provide information about bionomics of this bug for the first time.

MATERIAL AND METHODS

Part I

Material studied: MASCZ Het 150 & 151, 07.x.2017, 1 male and 1 female, Shahada (District Nandurbar), coll. Sarode, deposited in Modern College, Pune.

Bugs were studied under a Leica stereozoom (MZ6) microscope and also photographed with attached Canon Powershot S50 camera. Several images were stacked using CombineZP software and the images were processed with Adobe Photoshop CS5. Measurements were done with Erma stage and ocular micrometer and an accurate scale. The pygophore was dissected after treating the last three abdominal segments with hot 10% KOH, the phallic complex was dissected and the parameres and phallus were separated and mounted in polyvinyl lactophenol (PVLP) with lignin pink dye before photography. The dissected specimen was briefly rinsed with dilute acetic acid, followed by 70% alcohol, spread and mounted again.

Part II

Field work was done at two places in Dhule District (Shirpur and Sakri-Nizampur) during 15 June–15 November 2020. Several areas that harbor wild *Butea* plants were surveyed. Many adults and breeding pairs along with nymphs of the various stages were observed in the field. Some pairs were collected and reared at home in large plastic containers covered with nylon mesh and fed ad libitum with fresh, tender *Butea* shoots and cut leaves daily. In the field the bugs were observed to prefer tender shoot, leaves, and even flower buds. The containers were kept in room, near well-ventilated area in window, in the natural light cycle; temperature was not controlled. Egg laying, eggs, hatching process and nymphal development was recorded on these home-grown bugs. Since all this work was done at home in lockdown period (Covid-19 pandemic), microscopic examination and detailed description/ photography of different stages could not be carried out. All photos of habitat, mating pairs, eggs, and nymphs were captured on mobile camera (Redmi Note 7 or Redmi Note 9) or digital SLR (Canon EOS 760D). Data presented here are based on observations of 14 mating pairs (11 pairs were studied in home at Shirpur (by D. Jadhav) and three pairs were studied at home in Sakri (by R. Khairnar). Observations on eggs and nymphs were carried out using a small lens. Representative material of all nymphal stages is preserved in 70% alcohol and will be processed for microscopy work at Modern College later. Presently the material is with DJ and RK.

All the descriptions of eggs, nymphal stages and adults is entirely based on eggs that hatched at home. All the photos are also from the home reared population except the photo of the mating pair. There was no way to control temperature at home and so that variable is unknown. We regularly visited field populations nearby to check if the home grown nymphs are stunted or showing delayed development and we found no difference; however, these observations were done only with naked eye or with a small lens and are therefore 'gross'.

TAXONOMY

Family Coreidae Leach, 1815
Subfamily Coreinae Leach, 1815
Tribe Homoeocerini Amyot & Serville, 1843
Genus *Aschistocoris* Bergroth, 1909
Species *Aschistocoris brevicornis* (Dallas)

RESULTS

Part I

Observations on morphology:

Coloration and vestiture (male)

Body elongate, almost parallel-sided behind pronotum and slightly narrowed anteriorly. Colour ochraceous, ventrally mostly paler (except last 2 segments) than dorsal side. Entire body finely punctured, each puncture with fine, short, colourless seta; at some places, especially on head, lateral and anterior most side of pronotum, there are setigerous black granules; similar granules present on first three segments of antenna, fourth segment pilose; ventral part of head paler than dorsal side, setose but with very few blackish, setigerous granules; labium darker than adjoining area. Distinct, pale ochraceous line present along midline in posterior half of head dorsally, in anterior two-thirds of pronotum and entire length of scutellum.

Pronotum and scutellum sparsely covered with short, colourless setae arising from brown punctures. A few black setigerous granules also present on lateral margin, especially in anterior half, lateral margin pale, with fine granules. Ventrally all thoracic sterna more or less pale ochraceous with few scattered black setigerous granules on pro-, meso-, and meta-sterna laterally; one lateral black spot on each thoracic pleuron. Mesosternum and metasternum medially sub shining due to sparse setae, pleura setose like rest of the body; setae arising from colourless or black punctures. Hemelytra with corium and clavus as dark as pronotum, membrane translucent (revealing dark reddish brown tergites below), with prominent veins, shining with bronze tinge.

All legs identical in coloration, more or less matching dorsal coloration, spotted with black and finely setose: all coxae and basal two-thirds of femora pale ochraceous, distal third of femora, tibiae and tarsi reddish-brown; claws dark brown.

Abdomen with tergites dark brown, with pale border, and with two large median, round pale areas on segmental borders 4–5 and 5–6 (in both sexes), around the opening of "remnants of dorsal abdominal glands" (Schaefer 1964). Abdominal sternites medially with many black punctures with setae so that this part broadly appears greyish. This greyish median part flanked on each side by a pale stripe in which dark brown patches form an irregular pattern; further laterally connexivum pale in anterior half, slightly darker in posterior half. Overall posterior half of sixth and entire seventh sternum darker than preceding segments. Trichobothria prominent and in typical pattern: those on sternum three and four

closer to midline than those on the remaining sternites. Spiracles dark, situated closer to lateral than anterior margin of segment. Most of these coloration details are seen in (Image 1A,B) and (Image 2A–H).

Structure

Head

Sub quadrate, almost as broad as long, slightly convex above with deep median longitudinal sulcus behind clypeus that continues along as fine sulcus in posterior part. Head dorsally covered with black setigerous granules arranged in pattern, with median and lateral smooth lines. Eyes large, rounded, close to anterior angles of pronotum; width of head across eyes greater than width of pronotum across anterior angles. Ocelli prominent, closer to eyes than to each other, situated almost in line with posterior margin of eye. Preocellar pits prominent. Antenniferous tubercles situated at apex of head, slightly elevated and glossy. Clypeus and mandibular plates slightly declivous, visible between antenniferous tubercles (Image 2A,B). Labium long, almost reaching mid coxae, with two rows of setae along its length; boundary between first and second segments indistinct. Bucculae small; head, prosternum, and mesosternum distinctly sulcate medially, beneath labium. Antennae shorter than body, moderately robust, antennal I segment broadest, II and III slightly slender, these three segments densely covered with black setigerous granules, IV segment slightly thicker, spindle-shaped and finely punctured.

Thorax

Pronotum rhomboidal, slightly declivous towards head, its anterior margin emarginated behind head, posterior margin straight over scutellum, lateral margins straight; humeral angles slightly raised, sub shining (Image 2E,F). Scutellum as long as broad. Hemelytra with punctures on corium slightly larger than those on pronotum; clavus and corium identical in sculpture to scutellum, veins distinctly elevated and prominent, smooth and shining; membrane typically coreid with many longitudinal veins, not reaching apex of abdomen (in both sexes).

Metathoracic scent gland ostiole of characteristic shape, with well-developed peritremal lobes (Image 2I,J) but evaporatorium very small.

All legs slender, moderately long; fore coxae close together but mid and hind coxae well separated; femora slightly broadened distally, hind femora not reaching abdominal apex (Image 1A,B); tibiae of uniform diameter; tarsus three-segmented with first segment as long as remaining two, claws with globular, white pulvillus.

Image 1A–B. *Aschistocoris brevicornis* (Dallas): A—Dorsal habitus male (left) female (right) | B—ventral habitus male (left) female (right). © Hemant V. Ghate

Pregenital abdomen

Abdomen nearly parallel sided in basal three-quarters of its length, then slightly narrowed; abdominal segments almost as long as broad (Image 2G,H).

Female

Female longer (Image 1A), slightly broader in abdominal segments 4, 5, and 6 (Image 2H); in coloration ventrally paler than male**.** Other structures (barring genital segments) are nearly identical.

External genitalia

Male - Pygophore more or less rounded, more convex ventrally, flattened dorsally, with median crown-like projection on ventro-posterior margin and lateral triangular projection on each side; only these three projections visible in dorsal view (Image 2E) while ventrally about one half length of pygophore is visible.

Image 2A–H. *Aschistocoris brevicornis* (Dallas) morphology: A&B—Dorsal view of head, male | B—female | C&D—ventral view of head, male | D—female | E&F—Dorsal view of abdomen, male | F—Female | G&H—ventral view of abdomen, male | H—female | I&J—Lateral view of meso- and meta-thoracic pleura, red arrow pointing metathoracic scent gland area. © Hemant V. Ghate

Eighth segment not visible. Detached pygophore appears as shown here in dorsal, ventral and lateral views, respectively (Image 3E–G); dorsal bridge of pygophore narrow, its basal (anterior) opening elliptical while posterodorsal (posterior) opening somewhat flask shaped, narrow at base and wide distally. Parameres with broad base and blade-like distal portion (Image 3H). Dorsal view of phallus, just removed from pygophore, is shown here (Image 3I) along with dorsal view of everted phallus (Image 3J); these images show well developed articulatory apparatus, partly sclerotized theca, conjunctiva with pair of sclerotized ventral processes and other blunt, membranous processes; vesica partly sclerotized, short, and coiled.

Female - Seventh tergite emarginated, partially covering genitalia dorsally; ventrally seventh sternite with a deep median notch, lateral side to this notch is bisinuate; eighth paratergite with spiracle, ninth without. Appearance of female external genital plates as shown here (Images 2H, 3D).

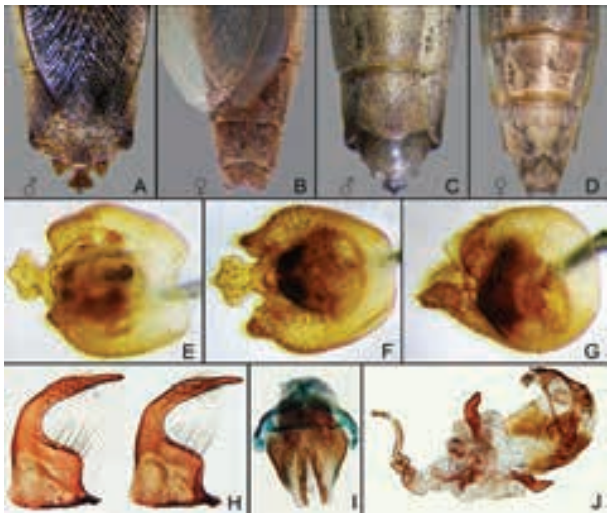

Image 3A–J. *Aschistocoris brevicornis* (Dallas) genitalia: A&B—genital segments of male | B—female, in dorsal view | C&D—genital segments of male | D—female, in ventral view | E–G—pygophore in dorsal, ventral and lateral view, respectively | H—Parameres | I—uneverted phallus in dorsal view | J—everted phallus in dorsal view. © Hemant V. Ghate

Measurement in mm of Shahada specimens (1 male / 1 female).

Total length – 13.8/16.5. Head length mediodorsally – 1.62/1.75; head width at antenniferous tubercles – 1.1/1.12; head width at eye – 1.62/1.7; head width between eyes – 0.87/0.92; eye diameter - 0.5/0.55; distance between ocelli – 0.5/0.5; antenna: first segment – 2.12/2.25; second segment – 3.0/3.37; third segment – 1.75/2.25; fourth segment – 1.8/2.25; labium: first segment – 0.37/0.75; second segment-1.0/0.87; third segment – 1.5/1.87; fourth segment – 1.25/1.37; pronotum breadth at anterior angles – 1.37/1.5; pronotum width at humeral angles – 3.0/3.25; median length of pronotum – 2.75/3.0; scutellum width at base – 1.37/1.5; scutellum median length – 1.62/1.75; prosternum – 1.0/1.1; mesosternum – 1.5/1.87; metasternum – 1.0/1.37; legs: fore coxa – 0.25/0.25; fore femur – 2.5/3.0; fore tibia – 2.0/2.25; tarsus with claw – 1.5/1.4; mid coxa – 0.5/0.5; mid femur – 2.8/3.0; mid tibia – 2.4/2.75; tarsus with claw – 1.5/1.75; hind coxa – 0.5/0.5; hind femur – 5.0/5.0; hind tibia – 3.5/4.0; tarsus with claw – 1.6/2.0; visible part of pygophore up to apex of crown-like projection – 0.82.

Part II

Observations on natural history

Habitat

Bugs were found in areas where there were many smaller, shrub-like *Butea* of about 2–6 feet (~60–175 cm)

height for dispersal, not usually found on a solitary tree. Bugs were observed to feed on petiole (mainly on petiole of 3 leaves which joins to the branch), on leaf veins of young parts, even flower buds and in the region where new branching is present. *Butea* trees are common in most areas; small (below 6 feet) and large trees are seen on the sides of roads, farms, and river banks, even on any vacant plot in the residential zones. These plants are, in fact, abundant at many places in Dhule District (Image 4A,B).

Mating and life cycle

Individual bugs as well as mating pairs of *Aschistocoris* were found in areas where at least 5 to 6 small (~1.8m) plants of *Butea* were present, in late June 2020 (first mating pair was located in Shirpur on 26 June while the most recent mating pair was observed on 10 November in the same area). Many mating pairs were found on central branch which was well covered by leaves; but pairs were also seen in the open on leaves or near apex of tender shoots and buds. Mating was typical of coreid bugs; the stout female and slender male could be easily identified (Image 4C). Eggs were laid on leaves or petioles or slender stems in wild; many stages of nymphs were also observed from July. This indicates that the breeding season for this bug is late June (perhaps depending on first pre-monsoon showers) to November. Since eggs laid in late November would develop to imago in December, part of December can be considered as equally important period.

The information presented below is based on 14 pairs reared at home and about 160 eggs that hatched successfully. Due to lack of sufficient preservative during this lockdown, only very limited material was preserved for future microscopic examination and over 80% nymphs or adults were released back to nature to avoid crowding in limited space. Observations were carried out with the help of a small lens only. -Typically total development took place in 25 to 27 days. Hatching success was 100% but nymphal mortality (especially in I and II instar) was observed in about 20 to 30% cases. Because many nymphs had to be released to avoid crowding, exact percentage of mortality in home reared eggs could not be documented. Photographs and brief morphological features of eggs and all five instars (nymphs) are presented here. Accurate measurement under microscope could not be carried out.

Eggs

Eggs are copper red, oval, with one side flat by which these are attached to the substratum (Size: length about 2mm, width 1mm). In nature eggs were deposited in clusters of 6 to 9 on leaf or 10 to 14 on petiole or tender stems in single or double line. Once eggs were found on nearby vegetation (grass leaves in close approximation). In home reared pairs, petiole and leaf surface were preferred as substratum, though some eggs were deposited on the wall of the plastic container. A partly double line of 14 eggs is seen on petiole (Image 4D) found in home reared pairs is illustrated here.

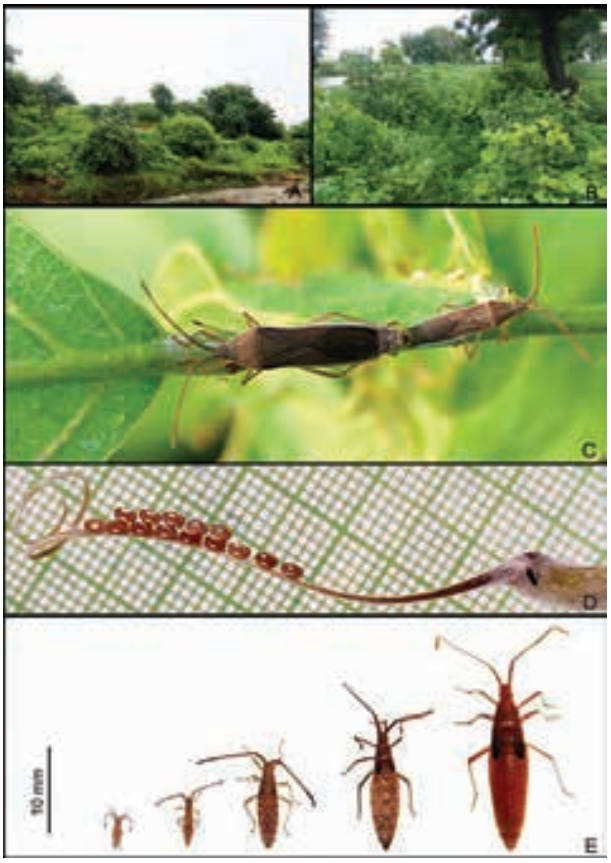

Image 4A–E. *Aschistocoris brevicornis* (Dallas) bionomics: A&B—Habitat | C—Mating pair, dorsal view (female on the left) | D—Eggs deposited on petiole by lab reared female (on graph paper with 1X1 mm squares) | E—All five nymphs together to show size increment and other features. © 4D by R. Khairnar; rest all by D. Jadhav.

First instar

Eggs hatched in 4 or 5 days. The first instar measures about 3mm from tip of head to tip of abdomen, with antenna about 2.5mm in length. Overall coloration of the first instar is pale greenish-yellow dorsally with prominent red dots on dorsal side, antennae and legs; ventral coloration pale green. Short erect setae arise from these red dots. The dorsal abdominal glands (DAGs) present on boundary between 4/ 5 and 5/ 6 segments appear as two round, red dots. First instar

duration was of 1 to 2 days (Image 5A).

Second instar

The second instar is about 5mm long, with width of head at eye about 0.5mm, maximum width of thorax 0.8mm and maximum width of abdomen 1mm. Overall body color is yellowish-brown. Antennae are 4-segmented, about 3.2mm long, first two segments are yellow brown with scattered red spots, III antennal segment is black in distal half while IV segment is red. The first three segments of antennae are cylindrical while the last segment is spindle shaped. Dark green patch develops on thorax where future wing pads begin to develop. Red coloration is seen on the lateral side of thorax as well. Dorsally two median red lines are seen from base of head along all thoracic segments. DAGs appear distinctly swollen, each with two dark brown spots. Body is light green ventrally with few red and black spots. Second instar duration was between 3 to 5 days (Image 5B).

Third instar

Third instar measures 7–8 mm in length from tip of head to tip of abdomen, width of head at eye 1.1mm, maximum width of thorax 1.4mm and maximum width of abdomen 2mm. Antenna measures about 5mm. Eyes become more globular and become bright red. Red lining on the dorsal side of thorax becomes darker. Wing pads begin to appear clearly in the third instar, are small, translucent and with few red spots; these just reach the first abdominal segment (see Image 6A). Body segmentation has become more pronounced. The DAGs are prominent, with two large lateral black spots and one small median black spot. Many dorsal red spots are partly black in posterior part while spots on legs become black. In about three days the nymph becomes darker, the black dots become prominent and show a symmetrical pattern; a median longitudinal pale line starts becoming prominent along entire length. The third instar required 5–6 days to go to the next stage (Image 5C).

Fourth Instar

The fourth instar measures about 10mm in length from tip of head to tip of abdomen, with maximum width of thorax 2–2.2 mm and maximum width of abdomen 3.5mm. Antenna is about 6mm long and pale brown. The nymph starts becoming grayish-green with dorsal red dots turning entirely brown. Wing pads grow up to 1.5–2 mm, are light green in color and possess border of brown dots. Wing pads can be observed easily by naked eyes from 13th or 14th day. Cream colored areas are mixed with brown dots on abdomen dorsally. Before entering 5th instar, nymph becomes overall much darker gray with brown spots; thorax is slightly darker than abdomen, DAGs are very prominent, enlarged and with dark triangular area in front. Fourth instar duration was 8–9 days and was the longest instar duration (Image 5D).

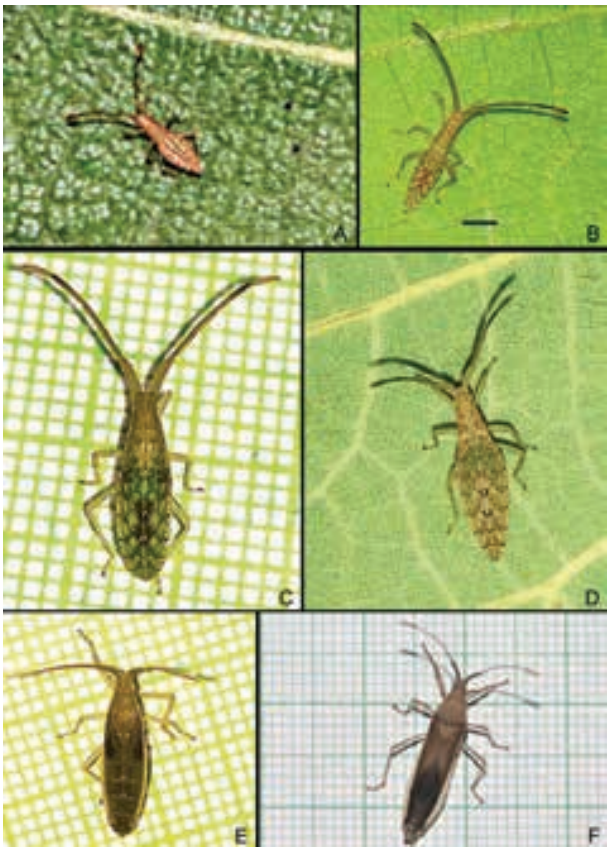

Image 5A–F. *Aschistocoris brevicornis* (Dallas) nymphs: A—I instar fresh, immediately after hatching | B–F—instars II, III, IV, V (after 2 or 3 days in that stage) and imago, respectively. (Graph paper in background with 1x1 mm squares). © R. Khairnar

Fifth Instar and adult or imago

Fifth instar shows body features similar to an adult except for the wing pads (see Image 6B) and body size. Overall color is darker than all previous stages and appears more grayish-green; entire lateral margin is pale cream like that of an imago. Eyes are large, round; wing pads reach middle of 3rd abdominal segment, appear greenish-gray with three stripes of dark brown color in early period (due to density of spots), but later become dark overall. The pale median longitudinal line observed on entire thorax is continued on to abdomen and is only interrupted by the DAGs and this line is flanked on either side by dark greenish area enclosing dark brown spots.

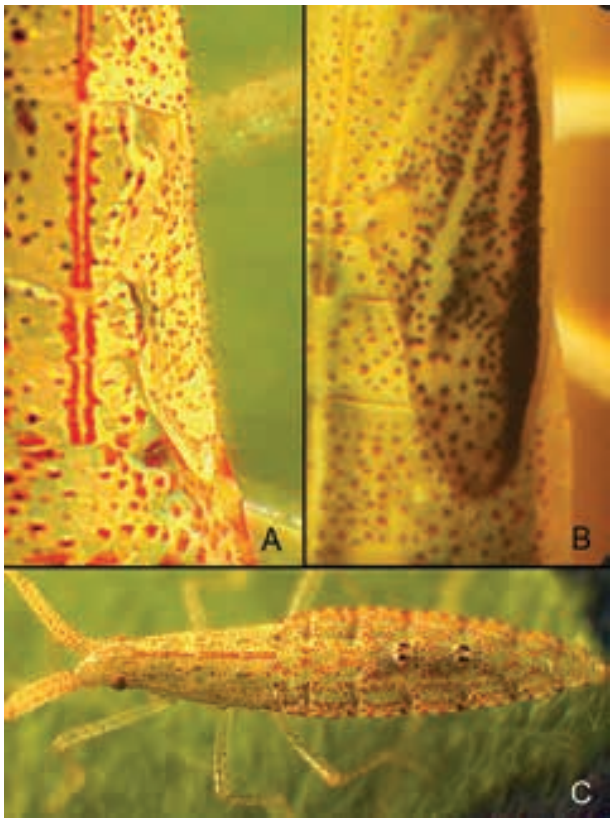

Image 6A–C. *Aschistocoris brevicornis* (Dallas) nymphal colouration: A—Wing pads III instar | B—Wing pads early V instar; note the color pattern | C—Coloration in live early III instar; note red spots, median red lines on thorax and the two DAGs. © R. Khairnar

Entire body is finely setose except the median pale line; body segments are well defined; abdominal glands bordered posteriorly with white, half circular lining, with two median red dots. Fifth instar is about 13mm, from tip of head to tip of abdomen; head width at eye 1.5–1.7 mm, maximum width of thorax 3.2–3.5 mm and maximum width of abdomen 3.5mm; antenna 8–9 mm long. Fifth instar lasts 4–5 days (Image 5E).

Imago measures about 14–17 mm long (accurate measurement under microscope not done), releases pungent smell if disturbed; female is larger than male (Image 5F, female; also see mating pair Image 4C for size difference). Two days after metamorphosis the imago assumes all adult coloration as illustrated in Image 1A,B; the other morphological features of all these *Aschistocoris* specimens from Dhule are identical to the specimens from Shahada that are described in detail in Part I. Thus there is no doubt that both Shahada and Dhule specimens belong to the same species *A. brevicornis.*

DISCUSSION

The material newly available to us accords well with the habitus photograph of the type specimen of *A. brevicornis* (Dallas) and with the recent redescription of the genus provided by Ahmad & Perveen (1983), which was based on material held by the Natural History Museum, London, originating from the localities mentioned by Dallas (1902) and Distant (1908, 1918). We are confident that our material is conspecific with the London specimens and so we have been able to redescribe and figure the species here in greater detail. The image of the type is available on Coreoidea Species File.

The male genitalia of *A. brevicornis* are in general very similar to those described by Ahmad & Perveen (1983) for the two species: *A. schaeferi* and *A. neonepalensis* mentioned earlier; especially the general appearance of the pygophore with a heart like or crown like apical structure, and the parameres, are very comparable; the everted phallus shown here is without thecal appendages; the conjunctiva with one pair of sclerotized, moderately long appendages and other short, lobe like appendages is also similar. Details of female genitalia could not be studied under present conditions but the gross appearance in ventral view differs from that described and illustrated by Ahmad & Perveen (1983) for the above two species. Perveen (1991) provided brief description of morphology with several line drawings of *A. brevicornis* specimens from NHM, London. Here again the diagrams are comparable to what we have presented here as images.

Differences from the related Indian and Nepalese species, namely *A. schaeferi* and *A. neonepalensis,* are indicated by Ahmad & Perveen (1983); however the status of the nominal species *Aschistocoris bombaeus* Bergroth remains unresolved. Bergroth (1909) described the species on the basis of a male collected in 'Bombay'(probably a larger area known as 'Bombay Presidency' at that time) while the type of *A. brevicornis* is a female. Bergroth's original description hints that his species is fairly similar to *A. brevicornis*; but actual type material must be studied to check if it is really a valid species or only a 'variety' as suggested by Distant (1918) or even if this is just a difference between male and female.

Occurrence of this species in Nandurbar and Dhule districts (which formerly were together as Dhule District), Maharashtra State, can be regarded as an addition to the known distribution of the species; it has now been collected again from the same host plant, *Butea*

monosperma. Besides, entire life history is completed on this plant in nature as well as in home reared individuals, establishing the fact that *Butea* is a host plant for this bug. Bhandara, one of the earlier localities known since the time of Distant, is about 600km east from Shahada. Apparently, this appears to be an overlooked species as there are no recent published records or a detailed, well-illustrated redescription of this species from any part of India, in spite of the fact that *Butea* is very widely distributed in India. In fact, according to Lohot et al. (2016) 'palas' (Marathi name for *Butea*) is found throughout the drier parts, often gregarious in forests, open grasslands and wastelands. It is a characteristic tree of the plains, often forming pure patches in grazing grounds and other open places, escaping extermination owing to its resistance to browsing and its ability to reproduce from seed and root suckers".

As far as the life history is concerned, the bug appears to be monophagous because it was not observed feeding on any other nearby plant, at least in different areas visited in Dhule District. Even then, none of the *Butea* plants that harboured 15–20 bugs at a time were seriously damaged or showed wilting or yellowing. Lohot et al. (2016) do not record this bug as a pest but they have recorded two other coreid bugs, *Anoplocnemis phasianus* (Fabricius, 1781) and *Physomerus grossipes* (Fabricius, 1794), as pests; however, none of these two species were found during the survey of several *Butea* plants in Dhule. In Dhule area the local name for *Butea* is 'khakra' and its red flowers (called as 'keshula' locally) are used in making natural color for festivals.

It is important to note here that there is no recently published information on this species from India, in spite of the fact that this is not a very rare bug in the areas surveyed. There was also no previous information on life history of this bug. Earlier work cited above only gives diagrams while we have provided many details of morphology of this bug, in the form of digital photographs, for the first time. Thus this note adds significant new information about *A. brevicornis.*

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17939–17949
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6285.13.3.17939-17949
#6285 | Received 10 June 2020 | Final received 05 March 2020 | Finally accepted 07 March 2020
PLATINUM OPEN ACCESS

COMMUNICATION

A new taxon of *Nacaduba* Moore, 1881 (Lepidoptera: Lycaenidae: Polyommatini) from Agasthyamalais of the Western Ghats, India

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Abstract: A new butterfly taxon, *Nacaduba sinhala ramaswamii* ssp. nov. (Lepidoptera: Lycaenidae: Polyommatini), is described from Agasthyamalais of southern Western Ghats in peninsular India. The new taxa can be diagnosed from all other *Nacaduba* of southern India and *N. sinhala* Ormiston, 1924 from Sri Lanka, by its distinct male genitalia. The early stages, larval hostplants, flight periods, ecology and the known distribution of the new taxa are discussed. The revised keys to all known *Nacaduba* of Western Ghats of peninsular India are provided.

Keywords: Butterfly, distribution, ecology, genitalia, Kerala, larval host plants, new taxa, subspecies.

ZooBank: urn:lsid:zoobank.org:pub:EB6EB702-006A-4F44-BAE3-1BEAAFF0F8DA

Editor: George Mathew, Mavelikara, Kerala, India.

Date of publication: 26 March 2021 (online & print)

Citation: Sadasivan, K., B. Kochunarayanan, F. Khot & R.K. Naicker (2021). A new taxon of *Nacaduba* Moore, 1881 (Lepidoptera: Lycaenidae: Polyommatini) from Agasthyamalais of the Western Ghats, India. *Journal of Threatened Taxa* 13(3): 17939–17949. https://doi.org/10.11609/jott.6285.13.3.17939-17949

Funding: None.

Competing interests: The authors declare no competing interests.

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Author contribution: KS—discovered the lifecycle, photographed and dissected the species for confirmation. BK—reared and documented the lifecycle. RK—manuscript revision and taxonomic comparison with related species. SRKN—reared and documented the lifecycle, Manuscript revision.

Acknowledgements: We thank George van der Poorten, Nancy van der Poorten, Krushnamegh Kunte, and Ben Price for their advice and help with reference materials. Satya Krishna Prakash for digitalisation of the hand drawn illustrations; Mr. Kandaswamy for his hospitality and permission to access the hostplant in his private estate at Thenkasi, Tirunelveli, Tamil Nadu to photograph the insect. We would like to thank Deepak Apte, ex-director BNHS for his support. We would like to thank Ashok Sengupta, Dipendra Nath Basu, Preeti Y, Anila VM for their help with the manuscript. We are grateful to members of Travancore Nature History Society, Thiruvananthapuram for their help in field.

INTRODUCTION

Line blues are small butterflies belonging to the subfamily Lycaenidae; essentially Indo-Australian in distribution (Corbet 1938). Their distribution ranges from India and Sri Lanka, to the whole of southeastern Asia, Australia, and Samoa. They are characterised by hairy eyes, anastomosis of veins 11 and 12 on forewings, male wings with purple gloss on the upperside, and underside of both sexes with dull whitish striae. Males of all species have battledore-shaped specialised androconial scales and some species have long ribbon scales on the upperside of wings that gives them a frosted look (Corbet & Pendlebury 1992).

Line blues are broadly classified according to the number of lines or bands seen in the underside of the forewing as four-line blues and six-line blues. Evans (1932) considered all line blues under the genus *Nacaduba* Moore, 1881. But according to the present taxonomic placements following Tite (1963), the old genus has been split into several genera under *Prosotas* Druce, 1891, *Petrelaea* Toxopeus, 1929, and *Ionolyce* Toxopeus, 1929, in addition to *Nacaduba*. *Prosotas* differs from *Nacaduba* by being smaller, having hindwing spaces between the striae more or less darkened, and the valva (claspers) of males being simple and ending in a long incurved point. *Prosotas* may or may not be tailed while *Nacaduba* are always with the tail on the hindwing (Corbet & Pendlebury 1992). The genus *Prosotas* has three species in peninsular India, namely: Common Line Blue *Prosotas nora ardates* (Moore, [1875]), Tailess Line Blue *Prosotas dubiosa indica* (Evans, [1925]), and White-tipped Line Blue *Prosotas noreia hampsonii* (de Nicéville, 1885). The genus *Petrelaea* and *Ionolyce* have one species each, namely, Dingy Line Blue *Petrelaea dana* (de Nicéville, [1884]) and Pointed Line Blue *Ionolyce helicon viola* (Moore, 1877) in peninsular India.

The *Nacaduba* males are dark blue or violet above, while females are paler or white with dark border on the upperside; and the underside of both sexes are brownish to grey with linear parallel white lines (Evans 1932). At present, eight species of the genus *Nacaduba* are recorded in peninsular India. This includes two species of four-line blues, viz., Large 4-line Blue (*Nacaduba pactolus continentalis* Fruhstorfer, 1916) and Pale 4-line Blue (*N. hermus sidoma* Fruhstorfer, 1916) as well as four species of six-line blues, viz., Trasparent 6-line Blue (*N. kurava canaraica* Toxopeus, 1927), Opaque 6-line Blue (*N. beroe gythion* Fruhstorfer, 1916), Rounded 6-line Blue (*N. berenice plumbeomicans* (Wood-Mason & de Niceville, 1881)), and Dark Ceylon 6-line Blue (*N. calauria evansi* Toxopeus, 1927) (Larsen, 1987). *Nacaduba calauria evansi* Toxopeus, 1927 and *N. berenice plumbeomicans* (Wood-Mason & de Niceville, 1881) were the two taxa that were only added later to southern Indian fauna from Nilgiris by Larsen (1987). The keys to the Indian forms of *Nacaduba* were given by Evans (1932), which are still being followed, except for the 4-line blues, whose markings lend themselves for easy identification, others of the genus need an examination of male genitalia for species confirmation (Corbet 1938). Ribbon scales in males are helpful in narrowing down the species, and these are absent in *N. kurava canaraica* Toxopeus and *N. calauria* evansi Toxopeus (Corbet & Pendlebury 1992).

Two individuals of *Nacaduba* line blues were photographed in October 2011 from Bonaccord Estate and later in September 2013 from a homestead in Vithura in Thiruvananthapuram District of southern Kerala, by the first author. These individuals were paler in coloration in comparison to the other *Nacaduba* line blues that were mud-puddling with them on a damp patch on the ground. Similar pale coloured individuals were also observed and photographed at Rosemala, Thenmalai in January 2018, and Thenkasi in Tamil Nadu in October 2018. A few days later in the same month, a *Nacaduba* female was observed ovipositing on young sprouting leaves from the cut stem of *Dimocarpus longan* Lour. (Sapindaceae) sapling, in Vithura (Fig. 1). Further investigation of the leaves revealed early stages of the *Nacaduba* species in different stages from egg to final instar larvae. These larvae were reared and details of the adults noted. The dissection of genitalia of male specimens were done and they were unlike any known *Nacaduba* from southern India and on further investigation they were found matching the Sri Lankan species *Nacaduba sinhala* Ormiston, 1924. The adults, early stages and larval host plant were similar to the Sri Lankan taxon, but the genitalia of the males were structurally different from it. This is the first confirmed record of this taxa occurring in the Western Ghats and thus the Indian mainland. We describe here the early stages and ecology of the taxa as well as provide a modified key to all known *Nacaduba* of the Western Ghats in peninsular India.

MATERIALS AND METHODS

The larvae of *Nacaduba* were raised on the leaves of its natural host plant *Dimocarpus longan* Lour. (Sapindaceae) under laboratory conditions and the details of each stage noted. The eclosed butterflies were

Figure 1. The study areas in Agasthyamalais in southern India.

studied. Taxonomy of *Nacaduba* follows Tite (1963). Identification of species follows Ormiston (1924), Evans (1932), Woodhouse (1947), and van der Poorten & van der Poorten (2018). Genitalia and external morphology were compared with specimens of *Nacaduba sinhala* Ormiston 1924, in the Ormiston's collection from Sri Lanka, housed in Bombay Natural History Society (BNHS), Mumbai, India. The genitalia were studied by soaking overnight in KOH, then dissected under Stereo-zoom microscope (HEADZ Model HD81) and preserved in glycerol. Illustrations were drawn by the first author using the Stereo-zoom microscope. The length of the forewing (FW) is measured as the longest straight-line distance from the wing base to the wing tip following Van hook et al. (2012). Terminology for wing patterns follows Evans (1932) and genitalia descriptions follow Corbet & Pendlebury (1992). Holotype and four paratypes are deposited in the insect collection of National Centre for Biological Sciences (NCBS), Bengaluru; other paratypes will be subsequently deposited in Zoological Survey of India (ZSI), Kozhikode and Bombay Natural History Society (BNHS), Mumbai.

RESULTS

***Nacaduba sinhala ramaswamii* Sadasivan ssp. nov.**

(Image 1A,B; Figure 2E)

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Materials examined (n= 5, 3 males and 2 females)

Holotype (Image 1A&B): NCBS-BH870, September 2018, male, Vithura (8.676N, 77.095E), Thiruvananthapuram District, Kerala, India, at 100m, both ex. larvae on *Dimocarpus longan* Lour. (Sapindaceae), coll. Kalesh Sadasivan.

Paratypes/Allotypes: NCBS-BH871 and NCBS-BH872, both males, bearing the same data as the holotype NCBS-BH870. NCBS-BH873 (Image 1C&D) and NCBS-BH874, both females, bearing the same data as the holotype NCBS-BH870.

Additional field records (Image 4)

1. Two male specimens were observed and photographed in the field by the authors from Rosemala, Shendurney Wildlife Sanctuary, Kollam District, Kerala State, India, January 2018, at 100m, from a habitation near secondary forest.

2. Four male specimens and three female specimens were observed and photographed in the field by the authors from a private estate plantation, Tenkasi, in October 2018.

3. One male specimen and one female specimen were observed in the field by Kalesh Sadasivan from Bonaccord Estate, Peppara Wildlife Sanctuary, Trivandrum District, Kerala State, India, October 2011 at

100m, from a habitation near secondary forest.

Description (Image 1A&B)

Male

Forewing length 14mm (n= 2). Antennae black checkered in jet black and white on the underside, apiculus white spotted on the lateral aspect; eyes black; palpal bases white haired, rest is greyish and tips black; legs vertically streaked in black and white, tarsus checkered in black and white; whole thorax dorsally covered in pale violet blue hairs laterally almost white above the origins of the wings, the hairs extending into the proximal abdominal segments; thorax underside clothed in white hairs; abdomen with shorter greyish-violet hairs on dorsum, underside paler, almost whitish, and the tip of the abdomen paler; hindwings tailed, tails black, tipped with white and with a brownish area in between them almost as wide as the white tip. Termen and tornus rounded more so in hindwing.

Upperside: General color is pale violet-blue with the central areas of both wings transparent and showing the bands on the underside. The whole wing surface is smeared in battledore androconial scales and long narrow ribbon scales, the latter giving a frosted look in photographs (Image 1A).

UpF: Upperside violet-blue; the underside forewing markings showing on upperside in males, especially in the discal and post discal regions. The transparent regions of wings more of brownish. Basal areas of wings: sub-marginal areas are more opaque with iridescent pale violet scales. Long pale bluish-violet hairs along vein 1a and dorsal margin (a continuation of the paler cilia), which may be lost in older individuals. A very thin marginal line brownish-black and this colour extends as short black streaks along all the veins reaching the proximal sub-marginal region. Cilia dark grey, turning paler at the tonus and dorsum. UpH: The general scheme is as in the forewing, with discal and post discal regions transparent and the underside bands showing through; basal, sub-marginal areas are opaque and clothed in iridescent violet scales. Marginal line black and extending though the veins into the sub-marginal region. Cilia dark greyish-brown, turning paler basally after the tornus and apex. Space 1a is ashy in the basal region and turning into brownish towards the tornus. The basal region, cell and the space 1b is clothed in very long pale violet blue hairs. Tornal region is darker at the areas of reflection of the tornal spots on the underside (Image 1A).

Underside: Generally pale brownish-grey with the basal, discal and post discal broad prominent bands on

Image 1. *N. sinhala ramaswamii* ssp. nov. Holotype male NCBS-BH870: A—Upperside | B—Underside. Allotype female NCBS-BH873: C—Upperside | D—Underside | © Kalesh Sadasivan.

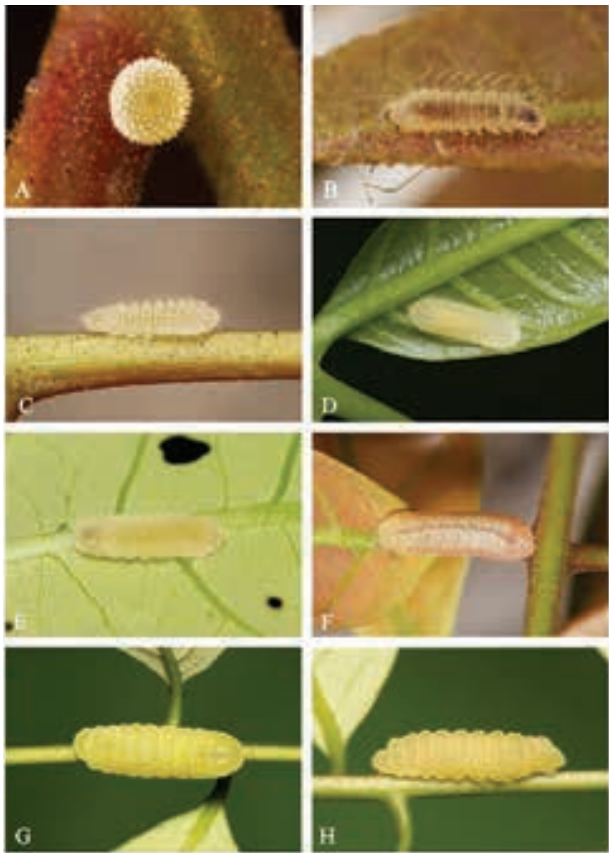

Image 2. *N. sinhala ramaswamii* ssp. nov. early stages: A—Egg | B—Egg-Larva | C—First Instar | D—Second Instar | E—Third Instar | F—Fourth Instar | G—Final instar dorsal view | H—Final instar lateral view | © Kalesh Sadasivan.

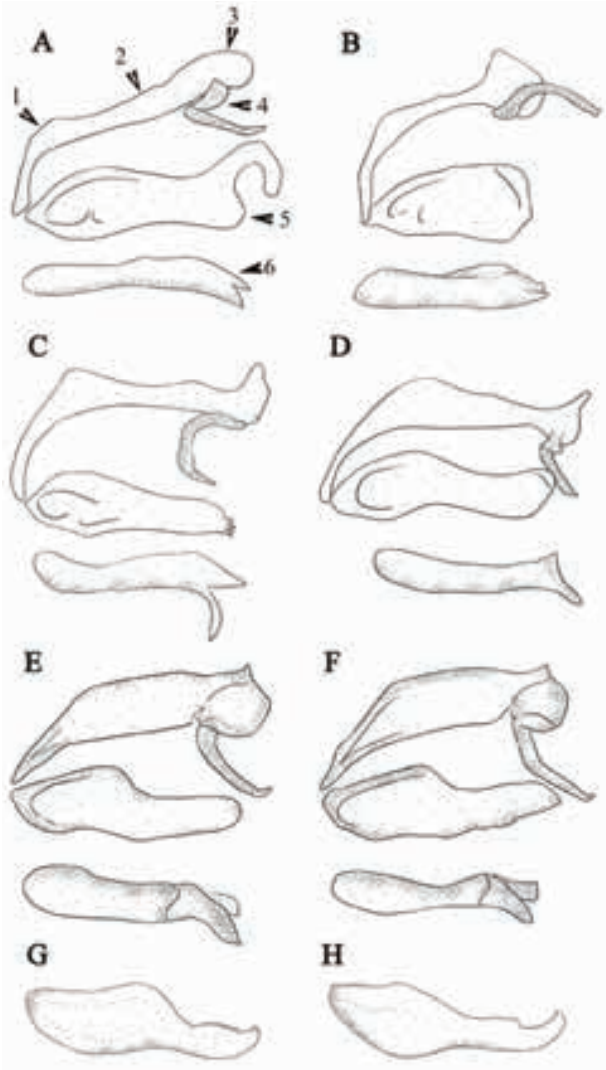

Figure 2. Male genitalia of *Nacaduba* with valva and allied structures from left lateral view with aedeagus separated (Parts labeled in A: 1—vinculum | 2—tegumen | 3—uncus | 4—sub-uncal process | 5—valva | 6—aedeagus): A—*N. kurava* | B—*N. calauria* | C—*N. beroe* | D—*N. Berenice* | E—*N. sinhala ramaswamii* ssp. nov. | F—*N. sinhala* | G—Valva *N. sinhala ramaswamii* ssp. nov. ventral view | H—Valva *N. sinhala sinhala* ventral view.

Image 3. *N. sinhala ramaswamii* ssp. nov. early stages: A—Pre-pupa | B—Pupa dorsal view | C—Pupa lateral view | D—pupa front view | E—Final instar larva with *Technomyrmex* ants attending them | F—Final instar larva with *Nylanderia* | © Kalesh Sadasivan.

both wings, these bands appearing crowded in the post-discal region of the hindwing; a sub-marginal series of almost heart-shaped greyish-brown spots basally and apically white bordered; and a marginal series of streaks of the same color capped with thin white marginal line and the thin dark marginal line. Three tornal spots on hindwing in spaces 2, 1a and 1b. UnF: The usual series of basal, discal and post discal bands, bounded by broad white streaks on either sides and grey on the inner side. The basal band is unbroken and extends from 1b-outer vein of the cell, and represented by a spot there after near the leading margin of the wing. The discal band is broken and a segment is seen in the cell and its distal continuation is broken into two parts; one part in space 7 is shifted outwards, lying between the discal and post-discal band; while the second part in space 8 is in line with the band. Segments of discal band in 1c and 2 are continuous and lies between the segment in outer cell and the postal discal band, thus making a 'Y' formation with them, though disjunct from distal cell band. The post-discal band is a zig-zag stack of parts in spaces 3–6, though more or less in continuity. The sub-marginal series of large heart-shaped dark grey spots spaces 2–6, whose sharp apices are directed towards the wing bases in spaces 1b-6. Marginal series of flattened crescentic dark grey spots from 1b-6. A thin inner marginal line of white from tornus to apex made of a series of thin curved lines in each space, fading after space 6. Another marginal line of dark grayish black is seen outside the white marginal line. Cilia greyish-brown, paler towards the tornus and almost whitish towards the dorsum. UnH: All the bands are broken and discontinuous. The basal band middle segment in cell is shifted basally in relation to the segments in spaces 1c and 7. A 'Y' shaped intersection is seen between continuous segments of

bands in space 1c and 2, with the distal cell segment of the discal and the post discal band segments in spaces 4 and 5. In addition the other segments of the band are seen just distal to mid space in spaces 1b 6 and 7. The heart-shaped sub-marginal series spots of dark grey are seen from space 3-6, that in space 7 is distorted. Marginal series of flattened crescentic dark grey spots from 3-6, followed by the white sub-marginal line and the marginal grey-black line. Cilia paler than that of forewing, greyish, and darker towards the tornus. Large tornal spot in space 2 occupying the position of the heart spots on other spaces, black at the center, distally laced with iridescent pale blue metallic scales, this is margined in pale orange all around and the orange margin is thin distally. Two smaller tornal markings of black orange and the metallic pale blue scales in spaces 1a and 1b, less than one-fourth size of the tornal spot in 2. Tail extending from vein between spaces 1c and 2, black and tipped with white (Tail on the left side of the Type male was lost in preservation). Bases of hindwings may have pale yellow and greenish-black scales below the basal band (Image 1B)

Male genitalia (Fig. 2E&G): From among the known species of *Nacaduba* from the Western Ghats, the general structure of the male genitalia of *N*. *sinhala* resembles *N*. *berenice* to some extent. The similarity is in the general morphology of valva, but the structure of vinculum, size and stricture of uncus and the anterior end of tegumen is quite different (Fig. 2E&G). The armature is very different from *N*. *kurava*, *N*. *beroe* and *N*. *calauria*. The nearest match is to that of *N. sinhala* from Sri Lanka, though there are some consistent differences. The shape and structure of annulus, vinculum and tegumen were similar to the nominate subspecies. The uncus was also similar in structure, but its size and that of the sub-uncal process was very variable amongst individuals of the same subspecies. The valva had significant structural differences from the nominate subspecies. On lateral view, with the whole armature in-situ, the harpe was smoother and shorter with the rounded distal coronal margin in *ramaswamii,* while it was more slender with irregular inferior margins and down-sloped coronal margin in *sinhala*. The first concavity on the inferior margin was place more proximally nearer to the angle of sacculus in *ramaswamii* while it was placed more distally in *sinhala* (Fig. 2F&H). On ventral view, the structure was similar in both subspecies, but the shape of valva was very different. The proximal part of the valva was thicker and medial border more angulated in *ramaswamii,* while it was thinner and margins sloping in *sinhala*.

Image 4. Field images of *N. sinhala ramaswamii* ssp. nov.: A—Male from Rosemala, Kollam, Kerala | B—Female from Thenkasi | C—Male from Thenkasi | D & F—Female ovipositing | E—Male Vithura, Trivandrum, Kerala | © Kalesh Sadasivan.

Image 5. Field images of *Nacaduba*: A—*Nacaduba pactolus continentalis* Fruhstorfer, 1916 | B—*N. hermus sidoma* Fruhstorfer, 1916 | C—*N. kurava canaraica* Toxopeus, 1927 | D—*N. beroe gythion* Fruhstorfer, 1916 | E—*N. berenice plumbeomicans* (Wood-Mason & de Niceville, 1881) | F—*N. calauria evansi* Toxopeus, 1927.

The harpe was thicker and less curved in *ramaswamii*, while it was slender and tip curved much more inward in *sinhala* (Fig. 2F). On detaching the claspers, the shape was almost as seen in the in situ view, but the distal end angle appeared more downcurved in *sinhala*, while it was slightly upcurved in *ramaswamii*, this was more evident on the ventral view (Fig. 2G&H). The aedeagus was more stockier and shorter in *ramaswamii*, while it was slender in *sinhala* (Fig. 2E&F). The coecum was larger and much globular in *ramaswamii*. The shaft was constricted a little distal to the middle of the shaft in *sinhala,* while no such constriction was seen in *ramaswamii*. The inferior border was more angulated in *sinhala*, in contrast it was smooth in *ramaswamii*. The supra-zonal sheath was sharper, more angulated and its tip angulated upwards in *ramaswamii*, while it was more smooth with a straighter tip in *sinhala*.

Female: Forewing length 13–14 mm (n= 2). The female is similar to the male on the underside. The termen and apices are more curved in comparison (Image 1C&D).

Upperside: General color is dark greyish-brown. UpF: Wing margins are broadly marked in dark grayish-brown, this band being thicker at the apex, followed by the termen, the leading edge and the distal half of the dorsum. The discal area with white patch, occupying the lower half of the cell, half of space 2, 3 from the origin and basal two-third of space 1b and basal half of space 1a. The basal half of the discal patch with pale blue iridescent scales and laterally the patch is pearly white. UpH: a pale discal patch of white that extends from the base to the sub-marginal zone, where the heart-shaped spots on underside are reflected as a series of spots. Space 1a is pale greyish. Reflections of the heart shaped sub-marginal dark spots, the marginal dark crescents, marginal lines are as in the males. Of the largest spot is the reflection of the tornal spot. Cell and proximal part of space 1 is clothed in long greyish blue hairs (Image 1D).

Underside: UnF and UnH as in male, except that the bands are a bit broader and so are the sub-marginal heart-shaped spots and the sub-marginal lines are more arched (Image 1C).

Variation

Male paratypes show little variation in patterns on upper and underside. The only difference in pattern was in the size of the heart shaped spots on hindwing spaces 4 and 5 which may be occasionally larger and meet the post-discal band, giving a crowded look. Size variation was considerable with forewing length varying from 13–15 mm. The females had significant individual variation, in addition to the size of the heart shaped spots on hindwing spaces 4 and 5, the extend of white coloration in uppersides of forewing disc and the hindwing was very variable. In a few individuals there were three well defined white spots in spaces 1b, 2 and 3. Size variation was observed with forewing length varying from 12 to 14 mm.

Diagnosis

Male upperside violet-blue, below ground colour is greyish to ashy, markings underside larger, ribbon scales present. The underside forewing markings well showing on uppersides in males. Male genitalia unlike any other species in peninsular India. Female upperside with shiny blue restricted to the basal half of both wings, upperside forewing with rest of the pale patch white.

Keys to *Nacaduba* of *Berenice* group from other regions of south-eastern Asia may not hold for taxa from Western Ghats, because of clinal variations and subspecies differences. We observed that the disposition of bands on underside are very variable, even on wings of a single specimen, and are not useful characters in diagnosing species. But the prominence of white streaks in them and the thickness of bands may be useful in identification. Males have straighter termens compared to females and this feature is more appreciable in open wing images. The transparency of wings and the underside marking showing through them is a useful character, but it must be used with caution, because in almost all species including the Opaque Six Line Blue *N. beroe*, the wings are transparent to a certain extend. This this is useful only in comparison of specimens in hand. The presence of ribbon scales are a useful character in males. But these must not be confused with normal long hairs in the cell and space 1b on upperside and the normal battledore shaped androconial scales. Androconial scales are structurally elongated, blunt ended short hair like scales distributed on the upperside of the male wings. Colors will sometimes loose brilliance, hairs may be lost in preservation and the colour of upperside may change with angles of incident light. The final word in determination of species must be based on male genitalia, which is distinct in each species.

Generally, in *Berenice* group (6-line *Nacaduba*) prominent white lines on the broad bands are characters that are exclusive to *N. kurava* and *N. sinhala*, while all other species have narrower bands with dirty or brownish stripes instead of pure white. The male *N. sinhala* is easily distinguished from all other *Nacaduba* in Western Ghats. Ground colour on underside is pale greyish compared to brownish of *N. beroe*, *N. calauria*, and *N. berenice* and much darker of *N. kurava.* The species has the palest blue on the upperside of males compared to all other *Nacaduba*. The rounded forewing termen of this species distinguishes it from species with straight termen, namely males of *N. kurava* and *N. beroe*. The presence of ribbon scales in males giving the frosted look on the upperside helps to differentiate the species, from males of *N. kurava* and *N. calauria*, that lack them. The species that have ribbon scales are *N. beroe* and *N. berenice*. From *N. berenice*, it can be differentiated by much large and prominent bands (narrow in *N. berenice)*, sub-marginal series of large heart-shaped dark grey spots (about the size of the tornal spot), with apices elongated towards the base of the wing, much darker than the grey inner stripes of the bands, more prominent on hindwings. From *N. beroe*, it can be distinguished by the rounded termen and the heart-shaped sub-marginal series. Females of *N. kurava* has heart-shaped sub-marginal series, but these are flattened and not elongated, and are always smaller than the tornal spot and not prominent on the hindwing and upperside of *N. kurava* has white discal patches. The male *N. sinhala* can be confused with females of other species too by the underside because of the rounded termen, but may be distinguished by the white discal patches of the other *Nacaduba* females. The distinct male genitalia in *N. sinhala*, compared to all other species is the final method of species confirmation in case of any ambiguity. Four-line *Nacaduba* of *Pavana* group are easily told apart by the lack of the basal band. But aberrations in *N. hermus* are known with extra band in basal region, in which case male genital differences have to be resorted to.

The female *N. sinhala,* cannot be confused with males, but they may be confused with other female *Nacaduba*. All are variable on the upperside with respect to the extent of blue and white. *N. kurava* and *N. sinhala* females have forewing distal end of the discal patch pure white. The blue of this patch is very pale sky-blue and is restricted towards the wing bases. In all other species the discal patch is darker blue completely with or without a purplish hue. Sometimes in *N. sinhala* females the discal patch may end in three post-discal

small white spots in spaces 1b, 2 and 3, clearly disjunct from the disco-basal patch. It is easily differentiated from *N. kurava* females by much the smaller size and the low elevational distribution <300m. Regarding elevational distribution, *N. kurava* is distributed above 700m in the subtropical and temperate forests; *N. beroe* is distributed from 200–700 m in mid-elevation forests, and all other species are seen commonly below 300m in evergreen and semi-evergreen jungles.

Etymology

The species is named after Lord Rama, signifying the connections across the sea to Sri Lanka.

Life History

Egg: The egg is a flat disc or turban shaped with the central region around the micropyle depressed a little. The superior surface is reticulated in a lotus petal pattern making quadrangular cells, the intersections of these lines bearing a centrally hollow tubercle. The color is dirty white. The egg is laid on the undersurface of the young leaves, axils and buds of the host plant *Dimocarpus longan* Lour. (Sapindaceae). Oviposition was observed usually in the afternoons where the females were seen in a fluttering weak flight searching for the best sites to lay eggs. Occasionally more than one egg was laid on same leaf but by different individuals (Image 2A). Size 0.75–1 mm

Larvae*:* The eggs hatched in about 2–3 days. The color of the egg larva was pale honey yellow (Image 2B). Head capsule is of the same color as the body, mouthparts brown and eyes are black. The bod bears moderately long pale yellowish semitransparent hairs, of these those on the dorsum and near the legs are longer. The tiny larva was seen keeping to the underside and scraping the lilac cuticle of that side, giving the larva its pinkish tinge when eaten. It is of the same color as the young leaf and very tiny to be seen, unless some sort of magnification was used. The young larva eats a part of the egg shell around the micropyle leaving behind the major part of the egg shell intact. The larva moves very slowly keeping to the undersurface of the leaf. The presence of these hatched out shell points out the presence of the egg larva. Size 2 mm. First instar: (Image 2C). The larva is pale waxy serous yellow in colour. The eye spots are black. The structure is like that of the egg-larva. Hairs are much shorter. The small caterpillar keeps to the underside of the freshest leaves, eating the substance in an irregular moth-eaten pattern. Size 2–3 mm. Second Instar: (Image 2D). The shape becomes more flattened. Colour is pale yellowish-white with a waxy appearance. Like in the previous instars it keeps to the concavities of the underside of the young leaves, eating in a moth-eaten pattern. Hairs are present, obvious and much shorter. Size 3–4 mm. Third Instar: (Image 2E). Similar to the second instar but a bit larger and coloured pale greenish white. The habits are as the previous instars. At this stage ants begin to attend to the larvae. Size: 0.5–0.75 cm. Fourth Instar: (Image 2F). The shape is almost onisciform and triangular in cross section. Colour is pale serous white with pink as follows- a dorsal thin line extending from segment 3 to 12, latero-basal thicker lines just above the flange covering the legs all along the side from the segment 2–12, whole of the segment 2 and 3. Of these three lines the dorsal line is the darkest. The central triangular plate on segment 2 is milky white so are the lateral organs on segment 12. The whole body is covered in very small, transparent star shaped tubercles giving a rough appearance on magnification. Hairs are seen on the lateral flanges, front and rear ends. Those on the lateral flanges are the shortest and curved and that on the front end and anal plate are longer, the latter being the longest. Size: 0.75–1 cm, habits are like the previous instars, but this a much bolder in feeding facilitated by the ants that attend it. Feeding is more active and the whole leaf margin is consumed instead of the cuticle and it prefers a little more mature leaflet. Final Instar: (Image 2G&H). The shape is onisciform. Segment 2 and anal plate is semi-circular. Mid dorsal plate in segment 2 is flower shaped and milky white. Each segment is flanged out and tumid giving a blunted serrated look. The highest point is at about the middle of the body. Colour is pale sap green with a waxy yellow shade especially along the baso-lateral flanges. Sometimes pink forms are also seen. Head is completely hidden under segment 2 and is pale greenish-yellow, eyes black and mouthparts pale brown. Body has sparse hairs along the baso-lateral flanges, on the edge of segment 2 and anal plate. Whole body is clothed in tiny tubercles giving a rougher texture on magnification. Spiracles circular and white. Segment 11 has the transverse gland opening at its hinder margin. Segment 12 bears the lateral organs, just postero-lateral ton the spiracles, and the tip of the thin extruded gland is pale pinkish-brown. Length 10–15 mm. Breadth 5–6 mm. The total duration of larval stage is 18–20 days.

Pupa: (Image 3B–D). Shape of the pupa is as in all *Nacaduba*, a short spindle with wide abdomen. On dorsal view, front is almost squarish with sides rounded off. The anal end is rounded. The broadest part on the pupa is around the level of the distal end of the wing cases. On lateral view, the head has a dorsal convexity,

the angle between head and thorax is obtuse, thorax is humped, the constriction between thorax and abdomen is very shallow and a smooth concavity. The highest point is at the mid-level of the wing cases. The abdomen has a uniform convexity. Pupa is secured with the mid-body band and the cremaster. The whole surface is finely reticulo-rugose and bears large black spots and tiny brown spots that coalesce to form blotches. The general colour is waxy pale yellowish-brown with a hue of rose on the head, thorax and wings; and opaque yellowish-pink with a brown wash on the abdomen. Wing cases are pale waxy brown. The whole body is marked in dark brown and black as follows- there is a dorsal band running from head to tail, this band has a large black spot near the joint of the head and thorax, there are two black spots as large as the anterior one, just above where the wings begin, another pair of black spots are present in the lateral ends of the first thoracic segment. A pair of spots in all segments on the dorsolateral aspect except in second thoracic segment. The dorsal band may form a large spot the rear end. Rest of the body bears tiny blackish-brown spots that may join with the adjacent ones. Pupation takes place under the leaf or on the stem of the plant (Image 3A). The butterfly eclosed in 7–10 days.

Ecological notes

The species appears to breed more during the north-east monsoons, though the breeding season extends from September to January, with peak in October. In Sri Lanka the larvae are attended by *Technomyrmex* (van der Poorten & van der Poorten 2013), while it is occasionally attended by *Technomyrmex albipes* (Smith, 1861) and *Nylanderia* species in southern India from stages 3-final instar (Image 3E&F).

Distributional range

This is the first record of the species *N. sinhala* outside its endemic range in Sri Lanka. Thus, the endemicity of the taxon is now limited to the Western Ghats complex (Western Ghats and Sri Lanka), more specifically Agasthyamalais and Sri Lanka. The altitudinal range is

Revised Key to *Nacaduba* line blues of Western Ghats of peninsular India

A. Underside forewing no basal pair of pale lines 4-line blues (*Pavana* group)

a) Underside forewing inner sub-marginal band on forewing continuous, broad and diffuse and continuous in both sexes (Image 5A) .... *Nacaduba pactolus continentalis* Fruhstorfer, 1916

b) Underside forewing inner marginal band of forewings made of separate narrow lunules in both sexes (Image 5B) .... *N. hermus sidoma* Fruhstorfer, 1916

B. Underside forewing with basal pair of pale lines: 6-line blues (*Berenice* group)

a) Termen of forewing straight in middle in spaces 2–6 in males, forewing apex produced, especially evident in open wing

i. Males pale violet blue, below markings regular and prominent ground color greyish, clearly showing through above, upperside hindwing disc in males not clothed in hair-like scales thus lacking the frosted look, females upperside forewing and upperside hindwing discal patch broad, pale bluish-white and lacks the white post discal spots (Image 5C). Male genitalia distinct (Fig. 2A) .... *N. kurava canaraica* Toxopeus, 1927

ii. Males upperside dark violet blue, below markings narrower, duller not clearly showing through above, ground color brownish, wings rounded than *N. kurava*; UPH disc in males clothed in hair like ribbon scales giving frosted look, females UFW discal patch restricted, bluish and traces of pale post discal spots, female UPH brown with bases purple blue (Image 5D). Male genitalia distinct (Fig.2C) ....*N. beroe gythion* Fruhstorfer, 1916

b) Termen of forewing convex, forewing apex rounded in both sexes

i. Ground color on underside browner, stripes narrow off-white; males upperside dark steely shining blue, ground color brownish, no ribbon scales hence lacking frosted look; markings on underside well-defined and narrow. Females upperside forewing discal patch restricted with bluish scales and traces of pale post discal spots, female UP purple (Image 5F). Male genitalia distinct (Fig. 2B)..... ..... *N. calauria evansi* Toxopeus, 1927

ii. Males upperside violet blue, below ground color greyish to ashy, markings on underside larger, ribbon scales present

a. Ground color browner in dry season and greyish in wet season form, stripes narrow off-white (Image 5E); underside forewing markings not well showing on upperside forewing. There may be heart-shaped spots on the sub-marginal areas of both wings in the west season form, but the spots are never elongated or thicker as in *N. sinhala,* especially in the forewings; females UPF and upperside hindwing broad discal bluish patch with no discal bluish spots, female upperside shining blue beyond the half of the wings, ribbon scales present on male forewing giving a frosted look. Male genitalia distinct (Fig. 2D).....*N. berenice plumbeomicans* (Wood-Mason & de Niceville, 1881)

b. Ground color pale greyish, stripes broad and white giving a crowded appearance especially on the post-discal region of hindwing. UNF markings well showing on UPF in males, female UP with shiny blue restricted to the basal half of both wings, UPF with rest of the pale patch white. Both sexes both wings with a sub-marginal series of large heart-shaped dark grey spots (about the size of the tornal spot), with apices elongated towards the base of both the wings, much darker than the grey inner stripes of the bands, more prominent on hindwings where they almost touch the post-discal bands (Image 4). Male genitalia distinct (Fig. 2E&G) .... ***N. sinhala ramaswamii* ssp. nov.**

below 300m (Fig. 1).

DISCUSSION

This paper adds one more taxa to the butterfly list of Western Ghats and hence to that of butterflies of mainland India. The Sri Lankan taxon was originally described as '*Nacaduba berenice ceylonica* Fruhstorfer'. Later, Ormiston (1924) renamed this, accepting the morphological differences as *Nacaduba sinhala;* and the Sri Lankan taxon representing *Nacaduba berenice* was named *Nacaduba berenice ormistoni* by Toxopeus (1927). *N. sinhala* was believed to be restricted to Sri Lanka as per Ormiston (1924), Evans (1932), Woodhouse (1947), and van der Poorten & van der Poorten (2018). The early stages and the larval hostplants of *Nacaduba sinhala* were documented by van der Poorten & van der Poorten (2013), as *Dimocarpus longan* Lour. (Sapindaceae). The species is said to be distributed from 100–900 m. The butterfly flies year round and is migratory, the peak flight season appears to be just before the start of the south-west monsoons according to van der Poorten & van der Poorten (2018). In contrast, the southern Indian subspecies seems to be non-migratory as far as known and present in low numbers all around the year. The peak flight season being during the North-East monsoons from September to November. The larva of the species is monophagus and feeds on *Dimocarpus longan* Lour. (Sapindaceae) both in Sri Lanka and South India. We found that the southern Indian taxon is morphologically similar to the nominate species from Sri Lanka but differs in its male genitalia structure. The differences and the geographical locations, suggest they have diverged possibly to a subspecies level. Further phylogenetic works might be needed to elucidate the molecular divergence and with sufficient variation it may be subsequently raised to species status.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17950–17962
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6596.13.3.17950-17962
#6596 | Received 21 August 2020 | Final received 03 January 2021 | Finally accepted 24 February 2021
PLATINUM OPEN ACCESS
COMMUNICATION

Does the size of the butterfly enhance detection? Factors influencing butterfly detection in species inventory surveys

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Abstract: Butterfly species' abundance and factors influencing butterfly detection in Chimmony Wildlife Sanctuary, Kerala was studied from April to June 2018. The survey was carried out on 15 tracks of 2-km lengths surveyed two times resulting in the sampling effort of 60km. A total of 141 species of butterflies belonging to two orders, six families and 103 genera were observed during the study, of which 15 species were recorded as endemic. The majority of butterfly species belonged to the families Nymphalidae and Lycanidae. The size of butterflies varies significantly among families with the largest butterflies recorded in Papilionidae and Nymphalidae and the smallest butterflies from Hesperidae and Lycanidae. The factors that determine butterfly detection during the count was determined using multiple regression. The number of detections had a linear relation with abundance, size, and activities of the butterflies. The model was highly significant and explained 86.9% of the variation in the detection of butterflies ($F=407.8$; $df=3$; $p<0.000$). Abundance had a primary influence on detection followed by the size and activities of the butterflies. Further studies on relative detectability of different species of butterflies in the diversity and abundance estimation would help in refining methods of assessment of butterflies.

Keywords: Abundance, Chimmony Wildlife Sanctuary, Hesperidae, Lepidoptera, Lycanidae, Nymphalidae

Editor: B.A. Daniel, Zoo Outreach Organisation, Coimbatore, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Velayudhan, A., A. Mohanarangan, G. Chandy & S. Biju (2021). Does the size of the butterfly enhance detection? Factors influencing butterfly detection in species inventory surveys. *Journal of Threatened Taxa* 13(3): 17950–17962. https://doi.org/10.11609/jott.6596.13.3.17950-17962

Funding: None.

Competing interests: The authors declare no competing interests.

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Author contribution: MA developed the concept, formulated hypothesis and did data analysis. AV did the field data collection, conceived the idea and carried out the preliminary analysis. GC and BS supervised the work and preparation of the final manuscript.

Acknowledgements: The authors are thankful to the chief wildlife warden for granting permission to conduct the research study in the Chimmony Wildlife Sanctuary (WL10-13885/2017 dated 23.03.2018). We thank the wildlife warden and other field staff for their support at the time of the survey.

INTRODUCTION

Butterflies are universally popular among all fauna. They are very beautiful and come in various sizes, shapes, and colours. Different patterns on their body enhance their aesthetic value (Gupta & Majumdar 2012). The Western Ghats can be classified into three biogeographical parts based on the status and distribution of butterflies. They are the southern Western Ghats, central Western Ghats and the northern Western Ghats (Gaonkar 1996). Because of high levels of species endemism, the Western Ghats is listed under 34 global biodiversity hotspots. The region is prominent among all other biodiversity hotspots (Myers et al. 2000). The butterfly fauna of the Western Ghats consists of 346 species of butterflies under six families (Bhakre & Ogle 2018).

Most of the inventory surveys were carried out by sampling through forest paths and trails without any information on the sample area (Sudheendrakumar et al. 2000; Sreekumar & Balakrishnan 2001; Aneesh et al. 2013), hence it was not possible to estimate population density. The systematic surveys using fixed width transect or using pollard walk (Isaac et al. 2011) helps to estimate the population density of butterflies with the same sampling effort by recording additional information on length and width of the area sampled. It is essential to determine the different factors that determine the detection probability. Species-wise differences in the detection probability of butterflies were reported in the studies carried out in the United Kingdom (Isaac et al. 2011).

The family Nymphalidae is the most dominant family with a high number of species. A detailed diversity study of butterflies in Chimmony Wildlife Sanctuary (CWS) has not been done yet. Previous studies reported 24 species of butterflies in the study area (George 2012). We have investigated butterfly species size and abundance influence on the detection of butterflies in inventory surveys at CWS.

METHODS

Study area

The study was conducted in Chimmony Wildlife Sanctuary, which spreads geographically within 76.417N and 10.402E and 76.560N and 10.483E in Thrissur District of Kerala State (George 2012). The sanctuary was established in the year 1984. The sanctuary consists of parts of Kodassery Reserve with an extent of 85.07km^2. It is bounded by Nelliampathy Reserve Forest on the east, Peechi-Vazhani Wildlife Sanctuary on the north-west, and Sholayar Reserve Forest on the south (Fig. 1). The mean annual rainfall is 3,130mm. The sanctuary has a tropical humid climate, with three distinct seasons, dry season (December–March) followed by the south-west monsoon (April–July), and north-east monsoon (August–November). Temperature varies from 38.5°C to 15.6°C during different seasons. The minimum temperature falls below 15.6°C during December. The area is also vulnerable to forest fires during the dry season. The sanctuary has more than 250 streams and six man-made waterholes. Diverse vegetation and favourable climatic conditions in the sanctuary could support many species of butterflies.

Butterfly abundance estimation

Butterfly species abundance was estimated using fixed-width transect method in CWS from April 2018 to August 2018. Totally, 15 strip transects of 2km were selected along paths with 2-m width on either side of the transect and sampled twice that resulted in the sampling effort of 60km. The surveys were conducted between 09.30h and 13.30h when the butterflies were most active. The butterflies observed in the field were photographed for further clarification and identification. Butterflies were identified using field guides (Kunte 2006; Palot 2015; Kehimkar 2016; Bhakre & Ogale 2018) and specialists were consulted in case of uncertainty in the identification of species. The butterflies were photographed using a Nikon 3100 DSLR camera with 18–50mm and 70–300 mm lens. The butterfly survey routes were marked with GPS (Fig.1).

Statistical analysis was performed by using Windows-based statistical package Microsoft Excel, PAST (Hammer et al. 2001) and SPSS. The diversity indices such as Simpson and Shannon-Wiener index of butterfly species from each habitat were analysed with the help of software PAST. Butterfly size difference among different families was tested using one-way analysis of variance (one-way ANOVA). The factors that determine the detection of butterflies, such as abundance, activities (0—resting; 1—foraging, flying, mud puddling, etc), size of butterflies were tested using multiple regression. Both response and independent variables were log-transformed due to positive skewness of data. Linearity was examined by plotting the relationship between the response variable (number of detections) and each predictor variable (abundance and size) using Lowess plot. To investigate multicollinearity between the environmental covariates, a correlation analysis was conducted before using

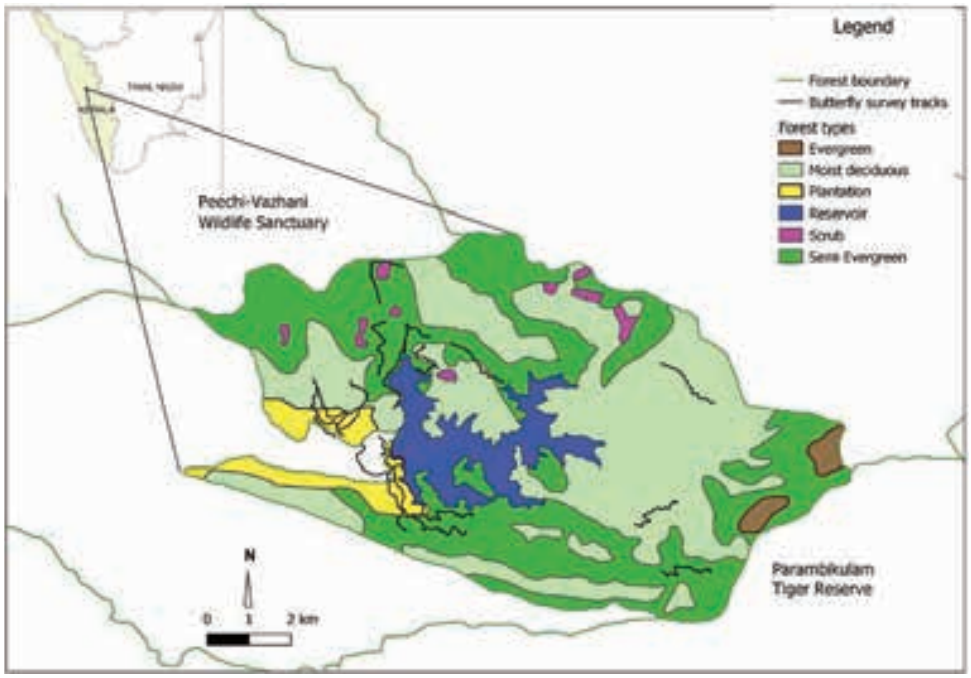

Figure 1. Chimmony Wildlife Sanctuary and butterfly survey routes in the study area.

multiple regressions to assess the relationships between the response variable and predictor variables, thereby providing valid parameter estimates and p values. The data were analyzed using SPSS Statistics 21 (IBM SPSS Inc., Chicago, Illinois, USA).

RESULTS

Totally, 141 butterfly species were documented in CWS from April to June 2020. Butterfly species composition varied among different families, with Nymphalidae and Lycanidae constituting 62%. Families such as Hesperidae, Papilionidae, and Pieridae were constituted 16.3%, 12.8%, and 8.5%, respectively. Only one species (Double-banded Judy) was recorded in the family of Riodinidae. Thus there is significant variation in the number of species recorded among different families (X^2=67.3; df=5; p<0.01). The majority of butterfly species belong to Nymphalidae and Lycanidae in Chimmony Wildlife Sanctuary.

In total, 15 species are found to be endemic to the Western Ghats region (Table 1). Butterfly species such as Indian Ace, Shiva Sunbeam, Blue Oakleaf, Danaid Eggfly, Gladeye Bushbrown, Malabar Tree Nymph, Tailed Palmfly, Tamil Catseye, and Southern Birdwing are endemic species (Images 1–45). There are four species of butterflies such as Orchid Tit, Malabar Banded Swallowtail, Crimson Rose, and Danaid Eggfly listed in the Schedule I of the Indian Wildlife Protection Act (1972). In total there are 20 species of butterflies that are catalogued in the Schedules of IWPA and provide protection to the butterflies. Common Lineblue is the most abundant butterfly followed by Common Crow and Common Emigrant in CWS. There were more than 100 individuals of all these butterflies that were recorded in the study area. There were 42 species that were recorded only once during the time of the survey.

Factors that determine detection of butterflies

The size of butterflies varies among families with the largest sized butterflies recorded from Papilionidae and Nymphalidae (102.8±23mm and 70.1±20.1mm). Hesperidae (37.5mm) and Lycanidae (30.6mm) are the smallest-sized butterflies. Pieridae and Riodinidae are the medium-sized butterflies (57.7mm and 45mm, respectively). There is a significant difference in the size of butterflies among different families (F= 118.20; df= 5; p< 0.001).

The relationship between the number of detection, abundance, and size of butterflies were tested using multiple regression. The number of detection had linear relation with abundance, size, and activities of the butterflies. The model was highly significant and explained 86.9% variation in the detection of butterflies (F= 407.76; df= 3; p< 0.00; Table 2). All the three predictors had positive abundance and size positively influenced number of detections. From the standardized

Table 1. Butterfly species and their abundance (data sorted in descending order) recorded in Chimmony Wildlife Sanctuary.

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
	Hesperidae					
1	Demon sp.	*Notocrypta* sp.	10			
2	Dusky Partwing	*Psolos fuligo*	8			
3	Water Snow Flat	*Tagiades litigiosa*	7			
4	Chestnut Bob	*Iambrix salsala luteipalpis*	6			
5	Golden Angle	*Caprona ransonnettii*	6			
6	Common Banded Demon	*Notocrypta paralysos mangla*	5			
7	Chestnut Angle	*Odontoptilum angulata*	4			
8	Common Spotted Flat	*Celaenorrhinus leucocera*	3			
9	Bevan's Swift	*Pseudoborbo bevani*	1			
10	Brown Awl	*Badamia exclamationis*	1			
11	Common Red Eye	*Matapa aria*	1			
12	Common Small Flat	*Sarangesa dasahara dasahara*	1			
13	Dark Palm-dart	*Telicota bambusae bambusae*	1			
14	Grass Demon	*Udaspes folus*	1			
15	Indian Ace**	*Halpe homolea hindu*	1			1
16	Indian Dartlet	*Oriens goloides*	1			
17	Pygmy Scrub Hopper	*Aeromachus pygmaeus*	1			
18	Restricted Demon	*Notocrypta curvifascia*	1			
19	Spotted Small Flat	*Sarangesa purendra hopkinsi*	1			
20	Suffused Snow Flat	*Tagiades gana silvia*	1			
21	Tamil Grass Dart	*Taractrocera ceramas*	1			
22	Tricoloured Pied Flat	*Coladenia indrani indra*	1			
23	Wax Dart	*Cupitha purreea*	1			
	Lycaenidae					
24	Common Lineblue	*Prosotas nora*	240			
25	Tailless Lineblue	*Prosotas dubiosa*	60			
26	Tiny Grass Blue	*Zizula hylax*	44			
27	Common Pierrot	*Castalius rosimon*	29			
28	Quaker	*Neopithecops zalmora*	29			
29	Lesser Grass Blue	*Zizina otis*	26			
30	Angled Pierrot	*Caleta decidia*	21			
31	Monkey Puzzle	*Rathinda amor*	15			
32	Common Imperial	*Cheritra freja butleri*	12			
33	Yamfly	*Loxura atymnus atymnus*	12			
34	Plains Cupid	*Chilades pandava*	10			
35	Fluffy Tit	*Zeltus amasa*	9			
36	Common Cerulean	*Jamides celeno*	8			
37	Many-tailed Oakblue	*Thaduka multicaudata Kanara*	8			1
38	Metallic Cerulean	*Jamides alecto*	8			
39	Common Hedge Blue	*Acytolepis puspa felderi*	5			
40	Dark Cerulean	*Jamides bochus*	5			
41	Banded Blue Pierrot	*Discolampa ethion*	3			

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
42	Dark Pierrot	*Tarucus ananda*	3			1(IV)
43	Gram Blue	*Euchrysops cnejus*	3			1
44	Shiva Sunbeam**	*Curetis siva*	3			
45	Dingy Lineblue	*Petrelaea dana*	2			
46	Indian Sunbeam	*Curetis thetis*	2			
47	Large Oakblue	*Arhopala amantes*	2			
48	Apefly	*Spalgis epeus*	1			
49	Common Silverline	*Spindasis vulcanus*	1			
50	Cornelian	*Deudorix epijarbas*	1			
51	Forget-me-not	*Catochrysops Strabo*	1			
52	Indigo Flash	*Rapala varuna*	1			1
53	Lime Blue	*Chilades lajus*	1			1
54	Malayan	*Megisba malaya*	1			
55	Orchid Tit	*Chliaria othona*	1	1		
56	Plain Hedge Blue	*Celastrina lavendularis lavendularis*	1			
57	Pointed Lineblue	*Ionolyce helicon viola*	1			1
58	Redspot	*Zesius chrysomallus*	1			
59	Slate Flash	*Rapala manea*	1			
	Nymphalidae					
60	Common Crow	*Euploea core*	168			
61	Chocolate Pansy	*Junonia iphita*	71			
62	Tamil Yeoman	*Cirrochroa thais*	46			
63	Clipper	*Parthenos Sylvia*	45			1
64	Common Four-ring	*Ypthima huebneri*	45			
65	Common Castor	*Ariadne merione*	24			
66	Rustic	*Cupha erymanthis*	21			
67	Bushbrown Sp.	*Mycalesis sp.*	18			
68	Common Evening Brown	*Melanitis leda*	18			
69	Great Eggfly	*Hypolimnas bolina*	13			
70	Striped Tiger	*Danaus genutia*	12			
71	Blue Tiger	*Tirumala limniace*	10			
72	Plain Tiger	*Danaus chrysippus*	10			
73	Tamil Lacewing**	*Cethosia nietneri*	10			
74	Angled Castor	*Ariadne Ariadne*	9			
75	Blue Oakleaf**	*Kallima horsfieldii*	8			
76	Common Nawab	*Polyura athamas*	8			
77	Dark Blue Tiger	*Tirumala septentrionis*	8			
78	Common Sailer	*Neptis hylas*	7			
79	Cruiser	*Vindula erota*	7			
80	Glassy Tiger	*Parantica aglea*	7			
81	Lemon Pansy	*Junonia lemonias*	7			
82	Autumn Leaf	*Doleschallia bisaltide*	6			1
83	Extra Lascar	*Pantoporia sandaka*	6			
84	Tailed Palmfly**	*Elymnia caudata*	5			

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
85	Commander	*Moduza procris*	4			
86	Gladeye Bushbrown**	*Mycalesis patnia*	4			
87	Grey Pansy	*Junonia atlites*	4			
88	Chestnut-streaked Sailer	*Neptis jumbah*	3			
89	Dark Evening Brown	*Melanitis phedima*	3			
90	Dark-branded Bushbrown	*Mycalesis mineus*	3			
91	Grey Count	*Tanaecia lepidea*	3			1
92	Yellow Pansy	*Junonia hierta*	3			
93	Black Prince	*Rohana parisatis*	2			
94	Blackvein Sergeant	*Athyma ranga*	2			1
95	Common Lascar	*Pantoporia hordonia*	2			
96	Danaid Eggfly**	*Hypolimnas misippus*	2		1	
97	Medus Bushbrown	*Orsotriaena medus*	2			
98	Tamil Catseye**	*Zipaetis saitis*	2			1
99	Black Rajah	*Charaxes solon*	1			
100	Blue Admiral	*Kaniska canace*	1			
101	Brown King Crow	*Euploea klugii*	1			
102	Common Five-ring	*Ypthima baldus*	1			
103	Common Three-ring	*Ypthima asterope*	1			
104	Double-branded Crow	*Euploea Sylvester*	1			
105	Great Evening Brown	*Melanitis zitenius*	1			1
106	Malabar Tree Nymph**	*Idea malabarica*	1			
107	Peacock Pansy	*Junonia almana*	1			
108	Plain Tawny Rajah	*Charaxes psaphon*	1			
109	Red-spot Duke	*Dophla evelina*	1			1
110	Tawny Coster	*Acraea terpsicore*	1			
	Papilionidae					
111	Common Mormon	*Papilio polytes*	73			
112	Narrow-banded Bluebottle	*Graphium teredon*	65			
113	Blue Mormon	*Papilio polymnestor*	64			
114	Southern Birdwing**	*Troides minos*	20			
115	Tailed Jay	*Graphium Agamemnon*	19			
116	Common Jay	*Graphium doson*	16			
117	Red Helen	*Papilio helenus*	15			
118	Five-bar Swordtail	*Graphium antiphates*	11			
119	Paris Peacock	*Papilio paris*	11			
120	Malabar Raven**	*Papilio dravidarum*	10			
121	Lime	*Papilio demoleus*	5			
122	Malabar Rose**	*Pachliopta pandiyana*	5			
123	Common Rose	*Pachliopta aristolochiae*	4			
124	Malabar Banded Swallowtail**	*Papilio liomedon*	4	1		
125	Common Mime	*Papilio clytia*	2			
126	Spot Swordtail	*Graphium nomius*	2			
127	Common Banded Peacock	*Papilio crino*	1			

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
128	Crimson Rose	*Pachliopta hector*	1	1		
	Pieridae					
129	Common Emigrant	*Catopsilia Pomona*	112			
130	Three-spot Grass Yellow	*Eurema blanda*	55			
131	Common Grass Yellow	*Eurema hecabe*	53			
132	Great Orange Tip	*Hebomoia glaucippe*	50			
133	Nilgiri Grass Yellow**	*Eurema nilgiriensis*	28			
134	Common Wanderer	*Pareronia hippia*	24			
135	Common Albatross	*Appias albina*	22			
136	One-spot Grass Yellow	*Eurema andersonii*	18			1
137	Lesser Gull	*Cepora nadina*	11			1
138	Mottled Emigrant	*Catopsilia pyranthe*	3			
139	Psyche	*Leptosia nina*	3			
140	Spotless Grass Yellow	*Eurema laeta*	1			
	Riodinidae					
141	Double-banded Judy	*Abisara bifasciata*	3			

**- Endemic species

Table 2. Multiple regression to investigate the effect of factors that influence detection of butterflies in Chimmony Wildlife Sanctuary.

Independent Variable	Predictor	Coefficients ± SEM		SPRC	t	p	Model (r^2)	model (p)
Number of detections	(Constant)	-0.476	0.185		-2.572	0.011	0.869	F= 407.76; df= 3; p< 0.00
	Activity	0.017	0.05	0.01	0.346	0.729		
	Abundance (log)	0.738	0.023	0.908	32.295	0.000		
	Size of butterflies (log)	0.190	0.048	0.108	3.978	0.000		

SEM—Standard error of mean | SPRC—Standardized Partial Regression Coefficient

partial regression, it was inferred that abundance (b_1= 0.74) had the primary influence on the detections, followed by size (b_2= 0.19), and activity of the butterflies (b_3= 0.02; Fig. 2).

DISCUSSION

Composition of butterflies varied among different families. A total of 141 species of 1,986 individuals were observed from CWS. Though the study was carried out in a limited period, the number of species reported was higher than earlier reports of the study area (George 2012). The number of species recorded in the study area was more than other protected areas in Kerala; Sudheendrakumar et al. (2000) recorded 124 species at adjacent Parambikulam Tiger Reserve. A total of 71 species from Aralam WS (Sreekumar & Balakrishnan 2001) have been recorded. The results, however, are not directly comparable outside the protected areas. The number of species recorded in Kerala Agricultural University was 139 species of butterflies (Aneesh et al. 2013). The reason for comparison is the geographical proximity of KAU compass to the study area. The study area is part of the network of protected areas such as Peechi-Vazhani towards north, Sholayar Reserve Forest in the south and Parambikulam Tiger Reserve in the east. The major habitat of the study area is evergreen and moist deciduous forest. Earlier studies recorded higher species diversity and richness in the similar habitats (Sudheendrakumar et al. 2000). Thus, the contiguous forest and evergreen habitat supports higher species diversity and endemism in the study area.

Family Nymphalidae and Lycanidae represented 62% of the total. Families such as Hesperidae, Papilionidae, and Pieridae were comparatively less. They are, 16.3%,

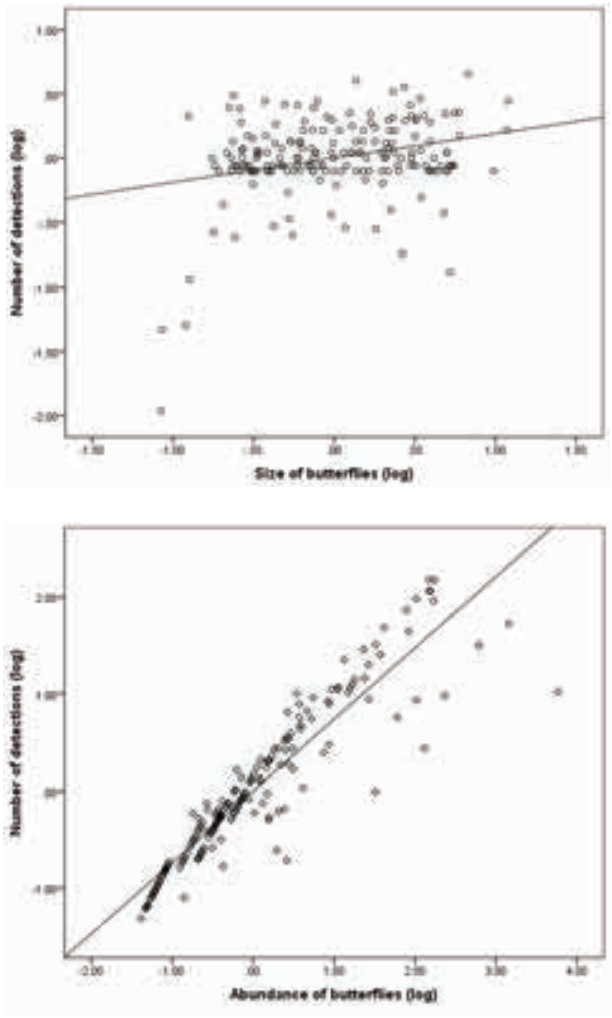

Figure 2. Relation between mean size of butterflies, abundance, activities: 0—Inactive-resting | 1—active-foraging, mud puddling, flying | and number of detections at Chimmony Wildlife Sanctuary.

12.8%, and 8.5%, respectively. Out of two butterflies in the family Riodinidae of Kerala and Western Ghats, one species (Double-banded Judy) was recorded from the study area during the period of study. There is a significant variation in the species composition among different families. Family Nymphalidae dominated over other families. In almost all the studies conducted in butterflies of Western Ghats (Sudheendrakumar et al. 2000; Sreekumar & Balakrishnan 2001; Aneesh et al. 2013) Nymphalidae is the family showing the maximum number of species because this is the family representing more number of species in the Western Ghats. The study area harbours 40.7% of butterfly species of Western Ghats (Bhakre & Ogle 2018).

In total there are 20 species of butterflies that are listed in various schedules of Indian Wildlife Protection Act (1972) that provide protection to these butterflies. Only 14.2% of butterflies of recorded species are protected under IWPA. Hence it is important to include all the endemic species in the IWPA and butterflies which are more charismatic, and rapidly declining species need to be listed under the schedules. Common Lineblue is the most abundant butterfly followed by Common Crow and Common Emigrant in CWS. The other species such as Common Mormon, Chocolate Pansy, Narrow-banded Blue Bottle, Blue Mormon, Tailless Lineblue, Three-spot Grass Yellow, and Great Orange Tip were recorded. Similar species composition was recorded in Parambikulam TR (Sudheendrakumar et al. 2000) and Aralam WS (Sreekumar & Balakrishnan 2001).

Factors that determine detection of butterflies

The study highlights the differences in the species detection based on size and abundance and importance of differences in detection probability of butterfly species inventory surveys. Butterfly species such as Common Lineblue, Common Crow, Common Emigrant, Common Mormon, Three-spot Grass Yellow, Narrow-banded Bluebottle, and Blue Mormon were more frequently sighted. All these species are conspicuous, larger in size, active flyers, and some species show mud-puddling behaviour as well. This could have resulted in higher abundance and detectability. Studies on butterflies have shown that detection of same species tends to vary according to habitats (Pellet et al. 2012). Further, survey technique could also influence the abundance and density estimation. Thus our preliminary examination on butterfly detectability showed the influence of size, abundance, and activities. The number of detection had a direct relation with the abundance, size, and activities of the butterflies.

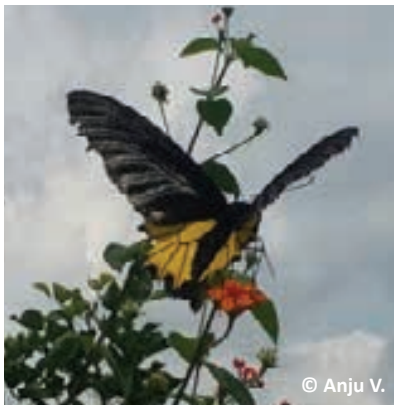

Image 1. *Troides minos*

Image 2. *Papilio polymnestor*

Image 3. *Pachliopta aristolochiae*

Image 4. *Papilio paris*

Image 5. *Graphium teredon*

Image 6. *Papilio demoleus*

Image 7. *Papilio liomedon*

Image 8. *Graphium antiphates*

Image 9. *Eurema blanda*

Image 10. *Eurema nilgiriensis*

Image 11. *Catopsilia pomona*

Image 12. *Appias albina*

Image 13. *Hebomoia glaucippe*

Image 14. *Cepora nadina*

Image 15. *Cethosia nietneri*

Image 16. *Idea malabarica*

Image 17. *Dophla evelina*

Image 18. *Junonia atlites*

Image 19. *Parthenos sylvia*

Image 20. *Kaniska canace*

Image 21. *Kallima horsfieldii*

Image 22. *Doleschallia bisaltide*

Image 23. *Elymnias caudata*

Image 24. *Tanaecia lepidea*

Image 25. *Euploea klugii*

Image 26. *Rohana parisatis*

Image 27. *Vindula erota*

Image 28. *Polyura athamas*

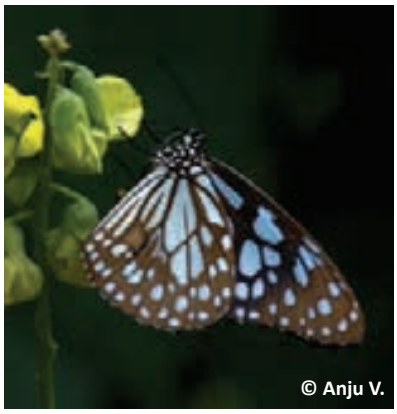

Image 29. *Tirumala limniace*

Image 30. *Ypthima huebneri*

Image 31. *Abisara bifasciata*

Image 32. *Caprona ransonnettii*

Image 33. *Odontoptilum angulata*

Image 34. *Tagiades litigiosa*

Image 35. *Tagiades gana silvia*

Image 36. *Halpe homelea hindu*

Image 37. *Cupitha purreea*

Image 38. *Cheritra freja butleri*

Image 39. *Thaduka multicaudata Kanara*

Image 40. *Loxura atymnus atymnus*

Image 41. *Zesius chrysomallus*

Image 42. *Chliaria othona*

Image 43. *Curetis siva*

Image 44. *Megisba malaya*

Image 45. *Deudorix epijarbas*

The model was highly significant and explained 86.9% variation in the detection of butterflies. Both abundance and size positively influenced the number of detections. From the standardized partial regression, abundance (b_1= 0.74) had the primary influence on the detection of butterflies, followed by size (b_2= 0.19) and activity (b_3= 0.02). Similar species-wise differences in the detection of butterflies were reported in the studies carried out in the United Kingdom (Isaac et al. 2011; Pellet et al. 2012). Further investigation on the detectability of butterflies based on size, colouration, and habitats will help to estimate population size rather than species abundance.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17963–17971
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.5885.13.3.17963-17971
#5885 | Received 21 March 2020 | Final received 11 November 2020 | Finally accepted 05 March 2021
PLATINUM OPEN ACCESS
COMMUNICATION

Dragonflies and damselflies (Insecta: Odonata) of the Kole Wetlands, central Kerala, India

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Abstract: A year-long study was conducted at the Kole Wetlands, a Ramsar site in central Kerala to document the diversity of dragonflies and damselflies and understand their seasonality. Checklist survey method was used to sample adult odonates in 30 randomly chosen locations. A total of 44 species (30 dragonflies and 14 damselflies) belonging to 33 genera and eight families were recorded in the study area. Species richness showed a peak in the post-monsoon season and a dip in the summer. The observations support the value of the Kole Wetlands in providing valuable resources for Odonata.

Keywords: Conservation, insect diversity, Ramsar site, seasonality, wetlands.

Editor: Ashish D. Tiple, Vidyabharati College, Wardha, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Chandran, A.V., S.K. Jose & S.V. Gopalan (2021). Dragonflies and damselflies (Insecta: Odonata) of the Kole Wetlands, central Kerala, India. *Journal of Threatened Taxa* 13(3): 17963–17971. https://doi.org/10.11609/jott.5885.13.3.17963-17971

Funding: This work was partially supported by Kerala State Biodiversity Board through WWF-India and C Achutha Menon - T R Chandra Dutt Fellowship 2019 of Centre of Science and Technology for Rural Development (COSTFORD) awarded to A. Vivek Chandran.

Competing interests: The authors declare no competing interests.

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Author contribution: SKJ and SVG designed the study. AVC and SVG collected data from the field. AVC analysed the data. AVC, SKJ and SVG wrote the paper.

Acknowledgements: We thank Subin K.S. for helping us in the field. We are indebted to Society for Odonate Studies (SOS), Kerala for the encouragement and technical support. SVG and AVC are thankful to Kerala State Biodiversity Board and Centre of Science and Technology For Rural Development (COSTFORD), Thrissur, respectively, for providing the financial support for the fieldwork.

INTRODUCTION

Insect diversity is threatened worldwide because of habitat loss, pollution, biological factors including pathogens, introduced species, and climate change (Sánchez-Bayo & Wyckhuys 2019). Because insects constitute the world's most abundant and speciose animal group and provide critical services within ecosystems, such an event cannot be ignored and should prompt decisive action to avert a catastrophic collapse of nature's ecosystems (May 2010). The situation urgently demands carrying out insect diversity studies in tropical countries like India, from where such information is lacking (Poorani & Verghese 2015). The order Odonata, popularly known as dragonflies (suborder Anisoptera) and damselflies (suborder Zygoptera) are primarily associated with wetlands and surrounding landscapes. Their adults are terrestrial/aerial and larvae are aquatic. They have been suggested as barometers for environmental change due to their sensitivity to anthropogenic stressors (Hassall 2015) and variation in habitat quality (Clark & Samways 1996). Globally, 6,312 species of odonates are known (Schorr & Paulson 2020). In India, 497 species and 27 subspecies in 154 genera and 18 families are known (Joshi & Sawant 2020; Kalkman et al. 2020; Payra et al. 2020; Subramanian & Babu 2020); 175 species of odonates have been recorded from Kerala till date (Society for Odonate Studies 2020).

The wetlands in Kerala are subjected to acute pressure owing to rapid developmental activities and indiscriminate utilization of land and water. The major issues facing the wetlands of Kerala are pollution, eutrophication, encroachment, reclamation, mining, and biodiversity loss (Kokkal et al. 2008). The Kole Wetlands is a Ramsar site since 2002 (Islam & Rahmani 2008), an important bird area since 2004 (Islam & Rahmani 2004), and a high value biodiversity area since 2009 (MoEF 2009). The Kole wetlands are low-lying tracts located 0.5–1 m below the mean sea level. Wetland agriculture, mainly paddy cultivation is the most important activity undertaken in these wetlands. The name Kole in the regional language Malayalam indicates bumper yield or high returns under favourable conditions (Srinivasan 2012). Kole is a biodiversity-rich agro-ecosystem and the flora (Sujana & Sivaperuman 2008), avifauna (Nameer 2002), herpetofauna (Sreehari 2009), and butterflies (Sarath et al. 2017) of the area have been well documented. This is the first attempt to document the odonate diversity of the Kole Wetlands.

METHODS

Study area

The Kole wetlands are spread over Thrissur and Malappuram districts in Kerala, covering an area of 13,632ha. Extending from the northern bank of Chalakudy River in the south to the southern bank of Bharathapuzha River in the north, this area lies between 10.3333°–10.6666°N & 75.9666°–76.1833°E (Johnkutty & Venugopal 1993). A unique feature of the Kole lands is that they remain submerged under floodwater for about six months in a year during the southwest monsoon. The Kole wetlands are split into three regions by the rivers draining them – Ponnani Kole lies to the north of Kecherypuzha; Thrissur North Kole lies in between Kecherypuzha and Karuvannur rivers; and Thrissur South Kole lies to the south of Karuvannur River (Figure 1). Even though they are human-modified ecosystems, Kole wetlands offer a variety of microhabitats for odonates (Image 1).

The study was conducted from February 2019 to February 2020. Thirty sampling locations were chosen randomly intending maximum spatial coverage of the Kole wetlands. Nine sampling locations each were chosen in Ponnani Kole and Thrissur South Kole. The more extensive Thrissur North Kole was assigned 12 sampling locations. One sampling location in each of the three regions of the Kole wetlands was visited every month. The others were visited as frequently as possible (Table 1). The checklist survey method was adopted for the study (Royer et al. 1998). In every site, the observer searched all the available microhabitats for an hour and recorded the species encountered. All the field visits were made between 09.00h and 11.00h when the adult odonates were observed to be most active (A. Vivek Chandran pers. obs. 01.ii.2019). Individuals encountered were photographed and identified referring to taxonomic monographs (Fraser 1933, 1934, 1936) and field guides (Subramanian 2005, 2009; Kiran & Raju 2013). Species which could not be identified readily in the field were caught using a sweeping net, their detailed photographs taken and released back. Systematic arrangement and taxonomy followed in the checklist is after Subramanian et al. (2018). The odonate species were categorized into five relative frequency classes, based on the proportion of their occurrence per sampling visit (Adarsh et al. 2014). The categories include very common (80%–100%), common (60%–80%), occasional (40%–60%), rare (20%–40%), and very rare (<20%). The study period was divided into three seasons for data analysis—summer (February, March, April, & May), monsoon (June, July,

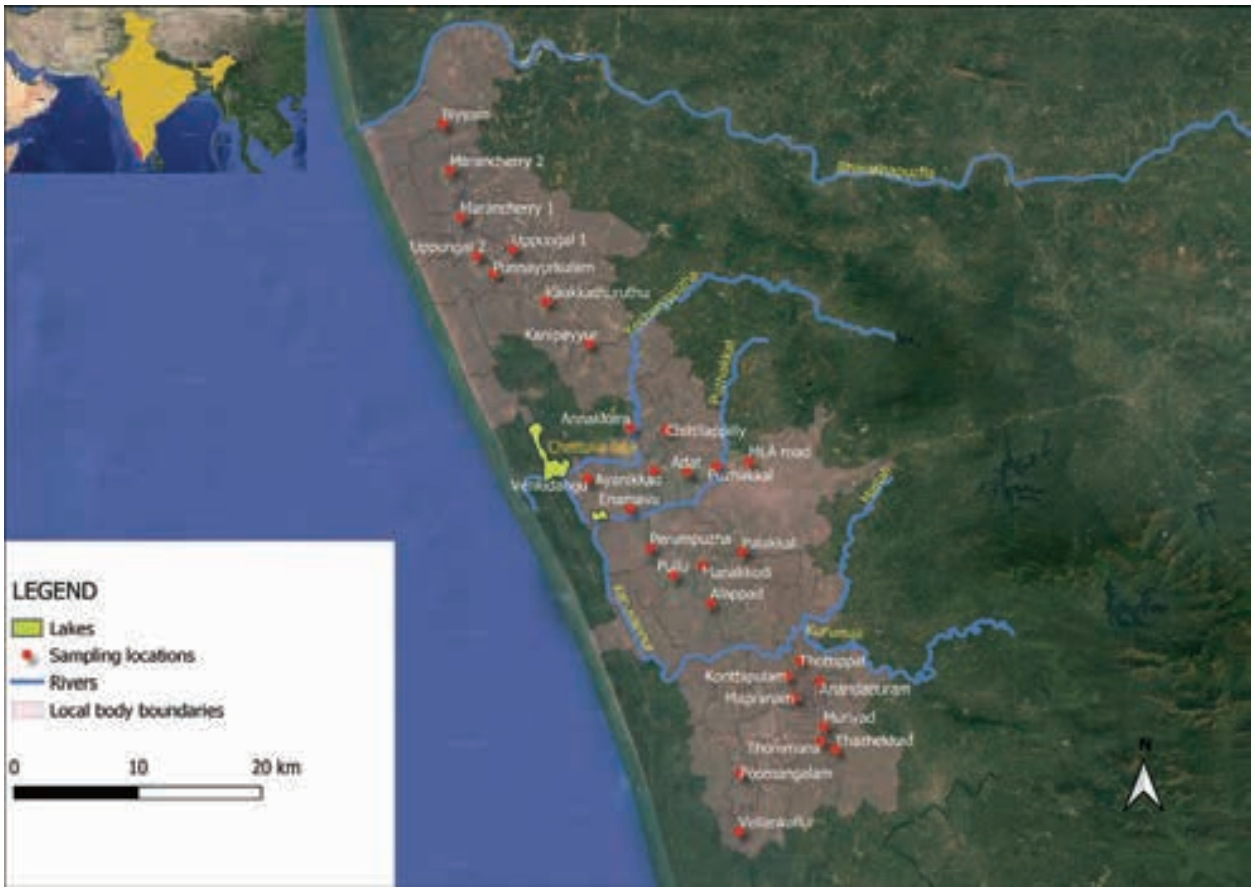

Figure 1. Study area: Kole wetlands, Kerala.

August, & September), and post-monsoon (October, November, December, & January).

RESULTS AND DISCUSSION

A total of 44 species of Odonata—30 dragonflies and 14 damselflies, belonging to eight families—were recorded from the Kole wetlands in the study (Table 2). Families Libellulidae (25 species) and Coenagrionidae (11 species) dominated while families Macromiidae, Lestidae, Chlorocyphidae, and Platycnemididae had only single species representatives. The relative frequency categorization shows that 13 species were very common, six common, six occasional, one rare, and 18 very rare. Species richness was highest in the post-monsoon season and lowest in the summer season.

One-fourth (25.14%) of the total number of odonate species known to occur in Kerala were recorded from the Kole wetlands in the present study. A similar study in the temporary water bodies of Coimbatore recorded only 21 species (Arulprakash & Gunathilagaraj 2010), but 52 species were recorded from the Kerala Agricultural University (Adarsh et al. 2014). Even though it is subjected to large fluctuation in the water level, the Kole wetlands never dry up completely in any time of the year. Clearly, this is advantageous to the odonates and explains their greater diversity when compared to temporary water bodies. These wetlands, however, lack shaded habitats and hence supports less number of species than the more habitat diverse Kerala Agricultural University campus. The relatively lesser number of damselfly species recorded from the Kole wetlands could be due to the scarcity of shade. Shade and spread of aquatic vegetation favour damselflies more than dragonflies (Fraser 1933; Subramanian 2005). Even though the field visits were made during day time, crepuscular species like *T. tillarga* and *Z. petiolatum* could be recorded as they were seen perched on tall grasses or in shaded places. Some species were observed to be microhabitat-specific. This included *P. calamorum* (Image 1), which occurred only in ponds with hydrophytes (all eight encounters in the study) and *C. marginipes* which could be observed only in shaded

Table 1. Sampling locations in Kole wetlands, Kerala.

Name of the site	Latitude	Longitude	Elevation (m)	Microhabitats	No. of visits made	Species richness
Puzhakkal	10.5415°N	76.1780°E	-1	B, E, F	12	19
Adat	10.5557° N	76.1477°E	-1	B, C, F	10	14
MLA road	10.5450°N	76.1963°E	1	C, D	10	11
Ayanikkad	10.5348°N	76.1277°E	0	A, C, D, F	11	18
Chittilappilly	10.5627°N	76.1358°E	-1	B, D, F	9	15
Annakkara	10.5623°N	76.1047°E	0	C, E, F	10	15
Enamavu	10.4724° N	76.1333°E	-2	B, C, F	9	13
Venkidangu	10.5270°N	76.1125°E	0	B, D, E, F	8	15
Perumpuzha	10.4821°N	76.1272°E	-1	B, C, D, F	9	19
Palakkal	10.4753°N	76.2022°E	-2	A, B, C, D, F	10	25
Manakkodi	10.4872°N	76.1733°E	-1	A, D, F	11	12
Pullu	10.4590°N	76.1455°E	-1	B, C, F	11	19
Alappad	10.4350°N	76.1702°E	-1	C, D, F	8	13
Thottipal	10.4033°N	76.2427°E	1	A, C, D, E	10	26
Konthipulam	10.3878°N	76.2366°E	0	A, F	12	22
Anandapuram	10.3806°N	76.2597°E	1	C, D	9	15
Mapranam	10.3634°N	76.2302°E	-1	B, C, D	11	19
Muriyad	10.3538°N	76.2591°E	0	A, B, C, D, F	10	23
Thommana	10.3397°N	76.2505°E	-1	A, C, F	9	28
Thazhekad	10.3306°N	76.2652°E	1	B, C, E, F	9	23
Poomangalam	10.3078°N	76.1861°E	0	B, C, E	8	16
Vellankallur	10.2951°N	76.2100°E	1	A, B, D, F	8	23
Kanipayyur	10.6565°N	76.0627°E	0	C, D, E	9	16
Kaakkathuruthu	10.6549°N	76.0475°E	-2	C, D, E	9	16
Punnayurkulam	10.6912°N	76.9986°E	-3	A, C, F	12	20
Uppungal 1	10.6942°N	76.0086°E	-3	A, B, C, F	10	22
Uppungal 2	10.6901°N	76.9977°E	-3	A, B, C, F	11	25
Marancherry 1	10.7380°N	75.9772°E	0	A, C, F	9	14
Marancherry 2	10.7395°N	75.9983°E	-3	A, C, E, F	8	20
Biyyam	10.7817°N	75.9727°E	0	A, E, F	8	16

areas of groves at the edge of Kole wetlands (all three encounters in the study). Species which showed such micro-habitat specificity were very rare. On the other hand, species such as *B. contaminata*, *R. variegata*, and *O. sabina* were seen in all microhabitats. They were the very common species. The number of migratory *P. flavescens* (Image 2) peaked in the months of October and November when hundreds could be seen foraging over the wetlands. The presence of species such as the endemic *A. keralensis* (Image 3) and the rare *Platylestes platystylus* (Image 4) (Emiliyamma et al. 2020) which was only recently recorded from peninsular India (Rison

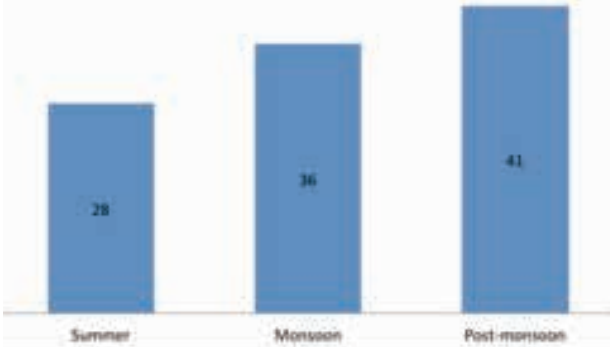

Figure 2. Species richness: number of odonate species recorded in each season.

Image 1. Microhabitats of Kole wetlands: A—Vegetated pond | B—Canal | C—Paddyfield with herb growth | D—Tall grass beds | E—Groves at the edge | F—Flooded area. © A. Vivek Chandran.

Table 2. Checklist of Odonata recorded from Kole wetlands, central Kerala, India.

	Name of the species	Common English name	Relative frequency in Kole wetlands	Endemicity	IUCN Red List status
	Class: Insecta				
	Order: Odonata				
	Suborder: Anisoptera				
	Family: Aeshnidae				
1	*Anax guttatus* (Burmeister, 1839)	Pale-spotted Emperor	VR	-	LC
2	*Anax indicus* Lieftinck, 1942	Lesser Green Emperor	VR	-	LC
	Family: Gomphidae				
3	*Ictinogomphus rapax* (Rambur, 1842)	Indian Common Clubtail	C	-	LC
4	*Paragomphus lineatus* Selys, 1850	Common Hooktail	VR	-	LC
	Family: Macromiidae				
5	*Epophthalmia vittata* Burmeister, 1839	Common Torrent Hawk	VR	-	LC
	Family: Libellulidae				
6	*Acisoma panorpoides* Rambur, 1842	Trumpet Tail	VC	-	LC
7	*Aethriamanta brevipennis* (Rambur, 1842)	Scarlet Marsh Hawk	O	-	LC
8	*Brachydiplax chalybea* Brauer, 1868	Rufous-backed Marsh Hawk	VC	-	LC
9	*Brachydiplax sobrina* (Rambur, 1842)	Little Blue Marsh Hawk	O	-	LC
10	*Brachythemis contaminata* (Fabricius, 1793)	Ditch Jewel	VC	-	LC
11	*Bradinopyga geminata* (Rambur, 1842)	Granite Ghost	VR	-	LC
12	*Crocothemis servilia* (Drury, 1770)	Ruddy Marsh Skimmer	VC	-	LC
13	*Diplacodes nebulosa* (Fabricius, 1793)	Black-tipped Ground Skimmer	VR	-	LC
14	*Diplacodes trivialis* (Rambur, 1842)	Ground Skimmer	VC	-	LC
15	*Hydrobasileus croceus* (Brauer, 1867)	Amber-winged Marsh Glider	C	-	LC
16	*Lathrecista asiatica* (Fabricius, 1798)	Asiatic Bloodtail	VR	-	LC
17	*Neurothemis tullia* (Drury, 1773)	Pied Paddy Skimmer	VC	-	LC
18	*Orthetrum chrysis* (Selys, 1891)	Brown-backed Red Marsh Hawk	VR	-	LC
19	*Orthetrum pruinosum* (Burmeister, 1839)	Crimson-tailed Marsh Hawk	VR	-	LC
20	*Orthetrum Sabina* (Drury, 1770)	Green Marsh Hawk	VC	-	LC
21	*Pantala flavescens* (Fabricius, 1798)	Wandering Glider	VC	-	LC
22	*Potamarcha congener* (Rambur, 1842)	Yellow-tailed Ashy Skimmer	VR	-	LC
23	*Rhodothemis rufa* (Rambur, 1842)	Rufous Marsh Glider	VC	-	LC
24	*Rhyothemis variegata* (Linnaeus, 1763)	Common Picturewing	VC	-	LC
25	*Tholymis tillarga* (Fabricius, 1798)	Coral-tailed Cloudwing	O	-	LC
26	*Tramea limbata* (Desjardins, 1832)	Black Marsh Trotter	O	-	LC
27	*Trithemis aurora* (Burmeister, 1839)	Crimson Marsh Glider	VR	-	LC
28	*Trithemis pallidinervis* (Kirby, 1889)	Long-legged Marsh Glider	C	-	LC
29	*Urothemis signata* (Rambur, 1842)	Greater Crimson Glider	VC	-	LC
30	*Zyxomma petiolatum* Rambur, 1842	Brown Dusk Hawk	VR	-	LC

	Name of the species	Common English name	Relative frequency in Kole wetlands	Endemicity	IUCN Red List status
	Suborder: Zygoptera				
	Family: Lestidae				
31	*Platylestes platystylus* (Rambur, 1842)	Green-eyed Spreadwing	VR	-	LC
	Family: Coenagrionidae				
32	*Aciagrion occidentale* Laidlaw, 1919	Green-striped Slender Dartlet	VR	-	LC
33	*Agriocnemis keralensis* Peters, 1981	Kerala Dartlet	C	EN WG	LC
34	*Agriocnemis pygmaea* (Rambur, 1842)	Pygmy Dartlet	VC	-	LC
35	*Ceriagrion cerinorubellum* (Brauer, 1865)	Orange-tailed Marsh Dart	C	-	LC
36	*Ceriagrion coromandelianum* (Fabricius, 1798)	Coromandel Marsh Dart	C	-	LC
37	*Ischnura rubilio* Selys, 1876	Western Golden Dartlet	O	-	NE
38	*Ischnura senegalensis* (Rambur, 1842)	Senegal Golden Dartlet	O	-	LC
39	*Paracercion calamorum* (Ris, 1916)	Dusky Lilly-squatter	VR	-	LC
40	*Pseudagrion australaisae* Selys, 1876	Look-alike Sprite	R	-	LC
41	*Pseudagrion decorum* (Rambur, 1842)	Three-lined Dart	VR	-	LC
42	*Pseudagrion microcephalum* (Rambur, 1842)	Blue Grass Dart	VC	-	LC
	Family: Chlorocyphidae				
43	*Libellago indica* (Fraser, 1928)	Southern Heliodor	VR	EN P	NE
	Family: Platycnemididae				
44	*Copera marginipes* (Rambur, 1842)	Yellow Bush Dart	VR	-	LC

Relative frequency classes: VC—Very Common | C—Common | O—Occasional | R—Rare | VR—Very rare. IUCN status: LC—Least Concern | NE—Not Evaluated. Endemicity: EN WG—Endemic to the Western Ghats | EN P—Endemic to peninsular India.

Image 2. *Paracercion calamorum*.

Image 3. *Pantala flavescens*.

& Chandran 2020) proclaim the importance of these wetlands as odonate habitats. The maximum number of species detected in the study (18) belonged to the very rare relative frequency class. This is suggestive of the utility of the survey method to detect species occurring in low abundances. It has to be noted that none of the odonate species recorded in the study is protected under the Wildlife Protection Act of 1972 (MoEF 2019) and all except two are listed as Least Concern species by the International Union for the Conservation of Nature and Natural Resources (IUCN 2020). The conservation of their wetland habitats is the only way to conserve these species. Our study presents the Odonata list of these wetlands for the first time and adds to the knowledge of insect fauna of India. The Kole wetlands provide

Image 4. *Agriocnemis keralensis*.

Image 5. *Platylestes platystylus*.

Image 6. *Pseudagrion australasiae* (dorsal and left lateral views of anal appendages in inset).

immense opportunities for ecological and behavioural studies of Odonata as many of the common species are present in large numbers and can be easily observed. The Kole wetlands are plagued by the problem of pollution due to the inflow of untreated sewage and indiscriminate use of pesticides in agriculture (Sujana & Sivaperuman 2008; Jayson 2018). These wetlands provide an ideal opportunity to study the response of odonates to varying degrees of pollution.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17972–17983

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

https://doi.org/10.11609/jott.5859.13.3.17972-17983

#5859 | Received 11 March 2020 | Final received 04 July 2020 | Finally accepted 23 February 2021

PLATINUM OPEN ACCESS

COMMUNICATION

Distribution and diversity of climbing species in Papum Pare District of Arunachal Pradesh, India

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Abstract: An investigation on the taxonomic diversity of climbing plants occurring in Papum Pare District, Arunachal Pradesh, northeastern India was conducted. A total of 187 species distributed over 55 families and 117 genera were collected and identified from the various forest areas of the district. Apart from one gymnosperm and five pteridophytes, all species belong to the angiosperm group. Fabaceae, Cucurbitaceae, Convolvulaceae, Vitaceae, and Apocynaceae were found to be the most dominant. *Piper, Dioscorea, Ipomoea*, and *Rubus* were dominant at the genus level. The study also revealed that majority of the climbers adopted twining mechanisms (43.85%) to ascend their host. It was found that a majority of the species were distributed below 500m with a decrease in diversity with altitudinal increment. The diversity of species above 1,500m was very limited where only 23 species were reported. Habitat degradation because of rapid developmental activities with limitation of the supporting tree species was found to be a serious threat to climbing plants.

Keywords: Climbing mechanism, diversity elevation zones, habitats, herbaceous vine, liana, northeastern India.

Editor: Anonymity requested.

Date of publication: 26 March 2021 (online & print)

Citation: Kashung, S., P.R. Gajurel & B. Singh (2021). Distribution and diversity of climbing species in Papum Pare District of Arunachal Pradesh, India. *Journal of Threatened Taxa* 13(3): 17972–17983. https://doi.org/10.11609/jott.5859.13.3.17972-17983

Funding: Partly funded by Ministry of Tribal Affairs, Govt. of India, through National Fellowship for ST for the 1st author.

Competing interests: The authors declare no competing interests.

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Author contribution: PRG and BS designed the objectives and plan of work. SK carried out the fieldwork, analyzed the data and wrote the manuscript. PRG and BS helped in data analysis, interpretation and manuscript correction.

Acknowledgements: We are thankful to the local people of the study area for their cooperation in documentation of the climber plants of the study area. We thank the forest officials and staffs of various forest divisions for their help during the field work. We thank the scientist and officials of Botanical Survey of India, Shillong (ASSAM) and Arunachal Field Station, Itanagar (ARUN) for herbarium facilities. We also express gratitude to the head of department, Forestry and Director, NERIST, for providing all necessary facilities.

INTRODUCTION

Around 50% of the families of vascular plants comprise climbing plants (Putz 1984). They occur in all forest ecosystems with its occurrence highest in tropical and sub-tropical forests (Quigley & Platt 2003; Bongers et al. 2005). The presence of over 8,000 climbing species under 130 families was predicted by Gentry (1991). Globally, studies on climbing species were focused primarily on lianas occurring in tropical forest communities by most researchers (Schnitzer et al. 2000; Ibarra-Manriquez & Martinez-Ramos 2002; Reddy & Parthasarathy 2003; Yuan et al. 2009; Muthumperumal 2011; Naidu et al. 2014). Despite the ecological and economic importance, the works on herbaceous vines are very limited and carried out only by a few researchers (Gallagher et al. 2011; Kumar et al. 2013; Suthari et al. 2014; Singh et al. 2015). Study on the diversity and distribution of climbing plants is still scanty in the Indian scenario when compared to their study worldwide. Despite having large forest covers under tropical and subtropical vegetation and rich diversity and density of the climbers, sufficient attention has not been paid to this group in India. Only a few studies have been carried out in the country in some selected sites particularly in the Eastern and Western Ghats, coastal and inland tropical dry evergreen forest and eastern Himalaya (Muthuramkumar & Parthasarathy 2000; Chittibabu & Parthasarathy 2001; Reddy & Parthasarathy 2003; Muthumperumal & Parthasarathy 2009; Chettri et al. 2010; Barik et al. 2015; Singh et al. 2015; Dvivedi et al. 2016). Majority of the work on climbing plants in India were reported from the Eastern and Western Ghats including some specific parts of southern states like Tamil Nadu, Pondicherry, Andhra Pradesh, and Andaman. Likewise, from the Himalayan and adjacent parts a few studies are available from Allahabad, Jharkhand, Uttar Pradesh, Arunachal Pradesh, Meghalaya, Sikkim, and Tripura (Chettri et al. 2010; Kumar et al. 2013; Darlong & Bhattacharyya 2014; Barik et al. 2015; Singh et al. 2015; Dvivedi et al. 2016).

The state of Arunachal Pradesh by virtue of its location in the eastern Himalayan range and its distinct phytogeographical unit is a confluence point of many floristic elements harboring a unique composition of plant species. The state is recognized as one among the 200 globally important ecoregions (Olson & Dinerstein 1998). The state is estimated to harbor at least 5,000 flowering plants belonging to 192 families and 1,295 genera thereby catering to more than 26% of Indian flora (Singh & Dash 2016). Many economically and ecologically important vines and lianas are distributed in the region including some rare and endemic species. Papum Pare District being the capital city located in the district, many forest areas are degrading at a faster rate for various developmental activities. Many of the climbers having surface rooting systems are also greatly affected due to the prolonged drought which sometimes leads to drying and death of the population of many species. Unless specific studies are designed and undertaken to explore the climbing species of the region, it could be difficult to assess the real diversity and distribution of these valuable components of the ecosystem.

The present study provides an account of the diversity and distribution of climbing plants of Papum Pare District of Arunachal Pradesh, India.

Study site

The study is confined to the Papum Pare District of Arunachal Pradesh, India, where the capital of the state, Itanagar, is located. The district covers a geographical area of 3,462km^2 and is located between 26.936–27.595 ^{0}N and 93.212–94.225 ^{0}E. It is bounded in the north by Lower Subansiri District, west by East Kameng District, east by West Siang District, and south by North Lakhimpur District of Assam (Figure 1). As the state is uniquely situated in the transition zone between the Himalayan and Indo-Burmese regions, a major part of the Papum Pare District is covered by thick forest with tropical, sub-tropical, and humid type of vegetation. Because of its geographical location, the district possesses a phenomenal range of biological diversity in flora and fauna and is also home to numerous tribal populations. The district is dominantly inhabited by the Nyishi tribe.

Data collection

The present study is the outcome of extensive periodical field surveys undertaken from 2015 to 2019 covering all the four subdivisions of the district, viz.: Balijan, Doimukh, Kimin, and Sagalee. For a better understanding of the extent of distribution of the climbing plant species of the region, the study area was subdivided based on the altitudinal range as below 500m, 500–1,000 m, 1,000–1,500 m, and above 1,500m. The presence of the climbing plants in each zone was then recorded through direct visual observation. The fieldwork comprises plant collection, taxonomic & ecological investigation including studies on their distribution, and climbing mechanisms. The collected species were identified using various taxonomic literature

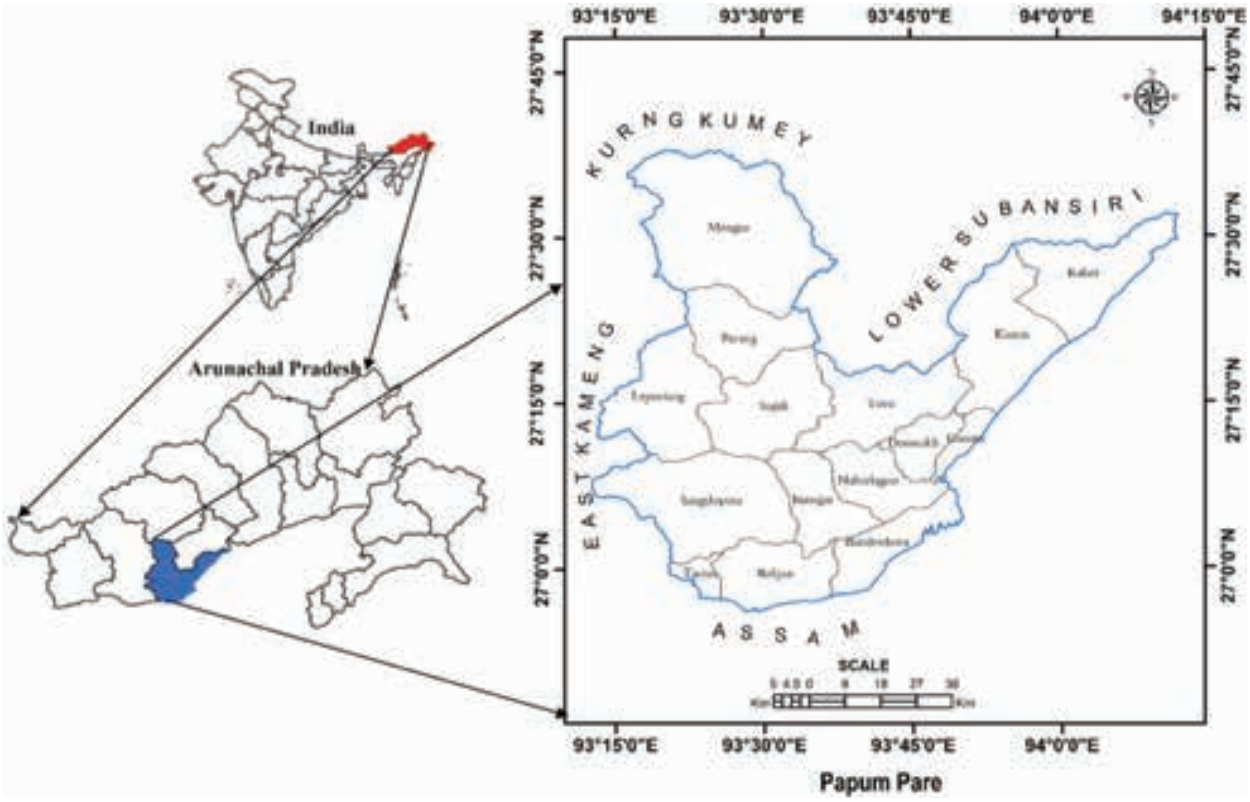

Figure 1. The study site.

(Hooker 1872–1897; Kanjilal et al. 1934–1940; Hajra et al. 1996; Giri et al. 2008–2009) and consultation with regional herbaria (ASSAM, ARUN). All the specimens were processed into mounted herbarium sheets as per the conventional methods of drying, poisoning, mounting, and labelling following Jain & Rao (1977). The processed herbarium specimens were deposited in the herbarium of the Department of Forestry, North Eastern Regional Institute of Science & Technology (NERIST), Nirjuli, Arunachal Pradesh, India.

RESULTS AND DISCUSSION

The present study revealed the rich diversity of climbing plants in Papum Pare District of Arunachal Pradesh. The exploration and field survey resulted in the documentation of 187 species belonging to 55 families and 117 genera distributed in the different forest areas of the district. Habit-wise analysis revealed that herbaceous vine constitutes the major group with 105 species followed by liana with 82 species. Majority of the species belong to Dicotyledons which comprises 150 species forming 82.87% while monocotyledon comprises 31 species forming 17.13% of the species recorded during the study. Gymnosperm is represented by only one species, *Gnetum montanum*, while pteridophyte is represented by five species. Among the families, Fabaceae is the most dominant with 21 species followed by Cucurbitaceae with 13 species, Convolvulaceae and Vitaceae with 12 species each, Apocynaceae with 11 species, and Araceae with 10 species. The 10 dominant families in the present study are presented in Figure 2. Around 50% of the families like Actinidiaceae, Basellaceae, Berberidaceae, Dilleniaceae, Gentianaceae, Icacinaceae, Primulaceae, Schisandraceae, Stemonaceae, Urticaceae

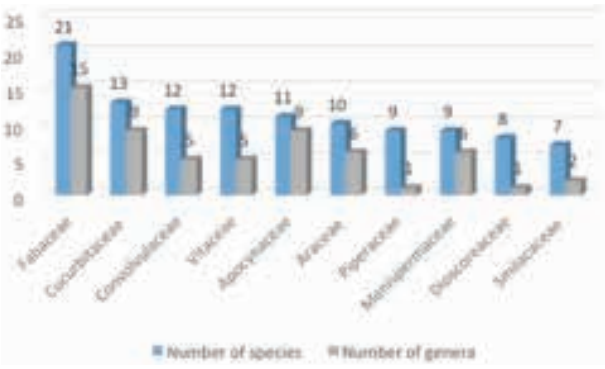

Figure 2. Dominant families with number of species and genera.

are represented by single species each. The families like Apocynaceae, Convolvulaceae, Cucurbitaceae, Fabaceae, and Vitaceae are also recorded as the dominant one in the flora of the state as well as other parts of the country (Chauhan et al. 1996; Hajra et al. 1996; Giri et al. 2008–2009; Muthumperumal & Parthasarathy 2009; Sarvalingam & Rajendran 2015). In terms of genera, *Piper* ranks the highest with nine species followed by *Dioscorea* (eight species), *Ipomoea* & *Rubus* (seven species each), *Smilax* (six species), and *Cayratia* (five species). The study by Gajurel et al. (2008) on the genus *Piper* from the state also indicated the richness of the species diversity in this genera.

The forests in the study sites are mainly tropical and subtropical with an intricate mosaic of habitats including open forests, dense forests, wasteland areas, riverine areas, and disturbed sites. The analysis of the habitat-wise distribution of species revealed a significant difference among the different habitats. The highest number of species was recorded from forest areas along the roadside and forest edges with 97 and 84 species, respectively. While a lesser number of species was recorded from inside the undisturbed dense forest (23 species) and disturbed forest (33 species) areas (Figure 3).

The distribution of the climbing species was found to be concentrated mainly in the lowest elevation zone of ≤500m with 136 species followed by 102 species in 500–1,000 m. The least distribution was observed in 1,000–1,500 m and above 1,500m with 51 and 23 species, respectively. The present observation of reduction in the number of species with increasing altitude is also in accordance with many workers who have also documented such findings worldwide (Schnitzer & Bongers 2002; Parthasarathy et al. 2004; Zhu 2008; Homeier et al. 2010). Along with the general distribution of the species, exclusivity of species distribution in different elevation zones was also observed. The exclusivity of the species distribution in ≤ 500m and > 1,500m zones was found higher with 44.85 % and 21.74%, respectively. While the exclusivity in the two intermediate zones of 500–1,000 m and 1,000–

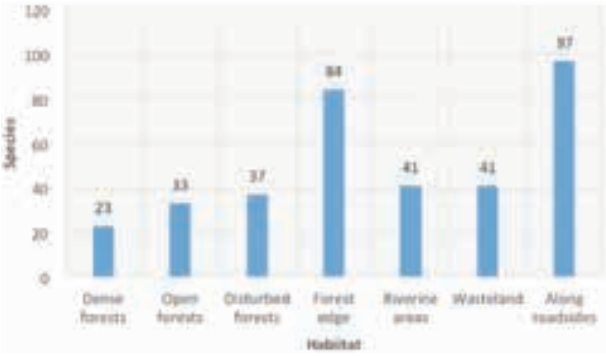

Figure 3. Different habitat types of climbing plants in Papum Pare.

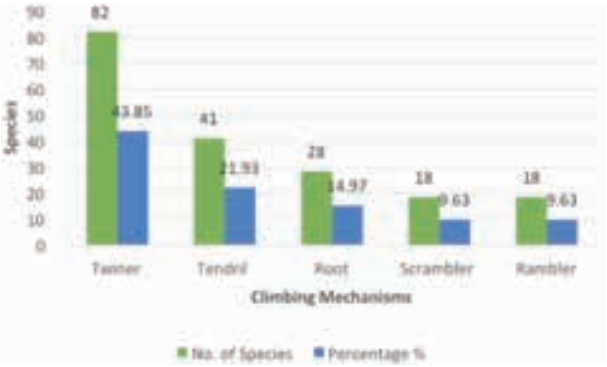

Figure 5. Climbing mechanisms.

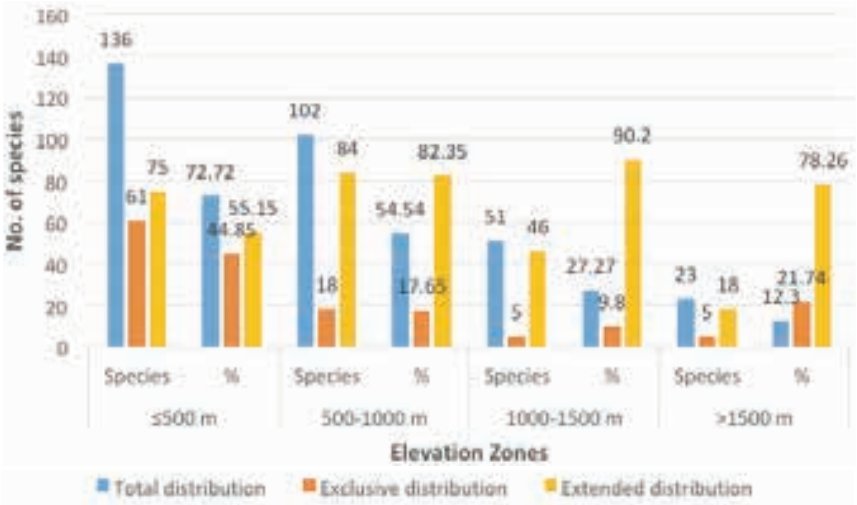

Figure 4. Distribution of climbing plants in different elevation zones of Papum Pare.

1,500 m was found comparatively less. Altogether, 99 species were found commonly distributed in more than one altitudinal range while the remaining 88 species were found restricted to a certain altitude only, including species like *Anredera cordifolia*, *Ampelocissus barbata*, *Anamirta cocculus*, *Cryptolepis sinensis*, *Dalhousiea bracteata*, *Decalepis khasiana*, *Embelia floribunda*, *Heterosmilax japonica*, *Lygodium flexuosum*, *Macroptilium atropurpureum*, *Myxopyrum smilacifolium*, *Natsiatum herpeticum*, and *Piper haridasanii*. The total species representation in the different elevation zones with its exclusive representation is provided in Figure 4 for easier observation and detection.

Species like *Argyreia nervosa*, *Caesalpinia cucullata*, *Cissampelos pareira*, *Cuscuta reflexa*, *Hedyotis scandens*, *Mikania micrantha*, *Paederia foetida*, and *Thunbergia grandiflora* were found most abundantly distributed in the study site. The invasive species like *Mikania micrantha*, *Thunbergia grandiflora*, and *Cuscuta reflexa* were found diversely distributed throughout the entire study area creating ecological and forest regeneration disturbances. Some species like *Ipomoea quamoclit*, *Macroptilium atropurpureum*, and *Pueraria montana* var. *lobata* although known to be highly invasive in other parts of the country (Reddy et al. 2008) were found restricted to only a few areas of the study site. The rare climbing species of the study area include *Abrus pulchellus*, *Anredera cordifolia, Anamirta cocculus*, *Argyreia capitiformis*, *Cryptolepis sinensis*, *Decalepis khasiana*, *Hodgsonia heterocilita*, and *Myxopyrum smilacifolium*.

The recorded plants were grouped into five types based on their climbing mechanisms used into twiner, scrambler (armed), rambler (unarmed), tendril climber, and root climber. Stem twining climber represents the highest group with 82 species (43.85 %) followed by tendril climber 41 species (21.93 %), root climber 28 species (14.97 %), and least representation by scrambler & rambler with 18 species each (9.63 %) (Figure 5). Higher diversity in the twining mechanism was also elucidated by various workers (Chittibabu & Parthasarathy 2001; Addo-Fordjour et al. 2008). One of the least diverse climbing mechanisms in the present study was climbing through hook/prickles in the scrambler group. Chittibabu & Parthasarathy (2001), however, in their work conducted in the tropical evergreen forest of Eastern Ghats had recorded a higher proportion of scrambler 23.1% diversity as compared to the tendril (19.2 %) and root climbers (3.85 %).

The list of all the recorded species with their family, habit & climbing mechanisms, threat status, and elevation ranges of distribution are presented alphabetically in Table 1.

CONCLUSION

The present study provides an account of the rich floristic diversity of the climbing plant of Papum Pare District of Arunachal Pradesh, which contributes to the overall biodiversity of the forests. Presently, many forest areas of the district are subjected to various anthropogenic pressures due to various developmental activities and the forest areas are degrading at a faster rate. It was also noticed that the important climbers of the forests of the region like *Piper* spp., *Dioscorea* spp., *Cryptolepis sinensis*, *Hemidesmus indicus*, *Hodgsonia heteroclita, Entada phaseoloides*, and *Cayratia pedata* are becoming rare day by day. Therefore, there is a need to create awareness among the local people for the conservation of these plants to ensure their continued existence in the long run.

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Table 1. List of climbing plant species of Papum Pare District.

	Botanical name	Voucher no.	Family	Habit	Habitat	Climbing mode	Elevation zone (m)
1	*Abrus precatorius* L.	Soyala K 152	Fabaceae	Liana	AR	Twiner	< 500
2	*Abrus pulchellus* Thwaites	Soyala K 121	Fabaceae	Liana	FE	Twiner	< 500
3	*Acacia caesia* (L.) Willd.	Soyala K 149	Fabaceae	Liana	R,DIF	Scrambler	< 500
4	*Acacia pennata* (L.) Willd.	Soyala K 169	Fabaceae	Liana	R, OF, AR	Scrambler	< 500
5	*Actinidia callosa* Lindl.	Soyala K 159	Actinidiaceae	Liana	DF, FE, OF	Rambler	500–1500
6	*Aeschynanthus bracteatus* Wall. ex A.DC.	Soyala K 034	Gesneriaceae	Vine	R, OF, AR	Root	< 500
7	*Allamanda cathartica* L.	Soyala K 003	Apocynaceae	Liana	AR	Rambler	< 500
8	*Ampelocissus barbata* (Wall.) Planch.	Soyala K 090	Vitaceae	Liana	AR, DIF, OF	Tendrils	< 500
9	*Anamirta cocculus* (L.) Wight & Arn.	Soyala K 161	Menispermaceae	Liana	AR, OF	Twiner	< 500
10	*Anredera cordifolia* (Ten.) Steenis	Soyala K 180	Basellaceae	Vine	AR	Twiner	< 500
11	*Argyreia capitiformis* (Poir.) Ooststr.	Soyala K 033	Convolvulaceae	Vine	WL	Twiner	< 500
12	*Argyreia nervosa* (Burm. f.) Bojer	Soyala K 034	Convolvulaceae	Vine	AR, WL, R, DIF	Twiner	< 500
13	*Asparagus racemosus* Willd.	Soyala K 115	Asparagaceae	Liana	R	Twiner	< 500
14	*Aspidocarya uvifera* Hook.f. & Thomson	Soyala K 085	Menispermaceae	Liana	DF, OF	Twiner	500–1500
15	*Bauhinia divergens* Baker	Soyala K 079	Fabaceae	Liana	FE	Tendril	500–1500
16	*Bauhinia khasiana* Baker	Soyala K 122	Fabaceae	Liana	AR	Tendril	< 500
17	*Bauhinia scandens* L.	Soyala K 165	Fabaceae	Liana	DIF, R, OF	Tendril	0–1000
18	*Beaumontia grandiflora* Wall.	Soyala K 020	Apocynaceae	Liana	AR	Twiner	< 500
19	*Berchemia floribunda* (Wall.) Brongn.	Soyala K 049	Rhamnaceae	Liana	FE	Rambler	500–1500
20	*Bougainvillea spectabilis* Willd.	Soyala K 032	Nyctaginaceae	Liana	AR	Scrambler	< 500
21	*Caesalpinia bonduc* (L.) Roxb.	Soyala K 179	Fabaceae	Liana	R, FE, OF	Scrambler	< 500
22	*Caesalpinia cucullata* Roxb.	Soyala K 171	Fabaceae	Liana	R, DIF	Scrambler	0–1000
23	*Calamus flagellum* Griff. ex Mart.	Soyala K 099	Arecaceae	Liana	R, AR	Scrambler	0–1000
24	*Calamus leptospadix* Griff.	Soyala K 142	Arecaceae	Liana	DIF	Scrambler	500–1000
25	*Calamus tenuis* Roxb.	Soyala K 127	Arecaceae	Liana	DF, DIF, OF	Scrambler	0–1500
26	*Cayratia corniculata* (Benth.) Gagnep.	Soyala K 145	Vitaceae	Vine	FE, AR	Tendril	< 500
27	*Cayratia geniculata* (Blume) Gagnep.	Soyala K 027	Vitaceae	Liana	FE, DIF	Tendril	< 500
28	*Cayratia japonica* (Thunb.) Gagnep.	Soyala K 004	Vitaceae	Vine	AR, DIF, WL	Tendril	0–1500
29	*Cayratia pedata* (Lam.) Gagnep.	Soyala K 050	Vitaceae	Vine	R	Tendril	500–1000
30	*Cayratia trifolia* (L.) Domin	Soyala K 028	Vitaceae	Vine	DIF, R, OF	Tendril	0–1500
31	*Centrosema pubescens* Benth.	Soyala K 001	Fabaceae	Vine	WL	Twiner	< 500
32	*Cissampelopsis volubilis* (Blume) Miq.	Soyala K 051	Asteraceae	Vine	FE, OF	Twiner	500–1500
33	*Cissampelos pareira* L.	Soyala K 029	Menispermaceae	Vine	AR, FE	Twiner	0–1000
34	*Cissus adnata* Roxb.	Soyala K 081	Vitaceae	Vine	AR, FE	Tendril	500–1000
35	*Clematis acuminata* DC.	Soyala K 162	Ranunculaceae	Vine	R	Tendril	< 500
36	*Clerodendrum splendens* G.Don	Soyala K 146	Lamiaceae	Liana	AR	Twiner	< 500
37	*Clerodendrum thomsoniae* Balf.f.	Soyala K 174	Lamiaceae	Vine	AR	Twiner	< 500
38	*Clitoria ternatea* L.	Soyala K 002	Fabaceae	Vine	AR	Twiner	< 500
39	*Coccinia grandis* (L.) Voigt	Soyala K 005	Cucurbitaceae	Vine	AR, FE, WL	Tendril	0–1000
40	*Codonopsis javanica* (Blume) Hook.f. & Thomson	Soyala K 172	Convolvulaceae	Vine	FE, OF	Twiner	500–1500
41	*Combretum decandrum* Jacq.	Soyala K 133	Combretaceae	Liana	DIF, FE	Twiner	0–1000
42	*Combretum indicum* (L.) DeFilipps	Soyala K 006	Combretaceae	Liana	AR	Twiner	< 500
43	*Crawfurdia campanulacea* Wall. & Griff. ex C.B.Clarke	Soyala K 052	Gentianaceae	Vine	FE, DIF, AR	Twiner	500– beyond 1500

	Botanical name	Voucher no.	Family	Habit	Habitat	Climbing mode	Elevation zone (m)
44	*Croton caudatus* Geiseler	Soyala K 176	Euphorbiaceae	Liana	AR, FE, R, DIF	Twiner	< 500
45	*Cryptolepis dubia* (Burm.f.) M.R. Almeida	Soyala K 046	Apocynaceae	Liana	DIF, AR	Twiner	0–1000
46	*Cryptolepis sinensis* (Lour.) Merr.	Soyala K 108	Apocynaceae	Liana	R, OF	Twiner	500–1000
47	*Cuscuta reflexa* Roxb.	Soyala K 055	Convolvulaceae	Vine	WL, DIF, AR	Twiner	All elevation zones
48	*Dalhousiea bracteata* (Roxb.) Benth.	Soyala K 113	Fabaceae	Liana	R, DIF, FE	Twiner	< 500
49	*Decalepis khasiana* (Kurz) Ionta ex Kambale	Soyala K 105	Apocynaceae	Liana	R	Twiner	500–100
50	*Derris marginata* (Roxb.) Benth.	Soyala K 053	Fabaceae	Liana	DF, AR, FE, R	Twiner	500–1500
51	*Dioscorea alata* L.	Soyala K 155	Dioscoreaceae	Vine	AR	Twiner	0–1500
52	*Dioscorea bulbifera* L.	Soyala K 107	Dioscoreaceae	Vine	R, FE	Twiner	0–1000
53	*Dioscorea esculenta* (Lour.) Burkill	Soyala K 177	Dioscoreaceae	Vine	AR	Twiner	< 500
54	*Dioscorea floribunda* M.Martens & Galeotti	Soyala K 183	Dioscoreaceae	Vine	FE	Twiner	< 500
55	*Dioscorea glabra* Roxb.	Soyala K 109	Dioscoreaceae	Vine	FE, AR	Twiner	500–1000
56	*Dioscorea hispida* Dennst.	Soyala K 110	Dioscoreaceae	Vine	AR	Twiner	500–1000
57	*Dioscorea oppositifolia* L.	Soyala K 007	Dioscoreaceae	Vine	FE	Twiner	< 500
58	*Dioscorea pentaphylla* L.	Soyala K 153	Dioscoreaceae	Vine	FE, AR	Twiner	0–1500
59	*Embelia floribunda* Wall.	Soyala K 075	Primulaceae	Liana	DIF, AR	Rambler	1000–1500
60	*Entada phaseoloides* (L.) Merr.	Soyala K 131	Fabaceae	Liana	DF	Twiner	500–1500
61	*Epipremnum aureum* (Linden & André) G.S.Bunting	Soyala K 031	Araceae	Liana	AR, FE	Root	< 500
62	*Epipremnum pinnatum* (L.) Engl.	Soyala K 064	Araceae	Liana	AR, DF, FE, OF	Root	All elevation zones
63	*Erythropalum scandens* Blume	Soyala K 102	Oleaceae	Liana	R	Twiner	500–1000
64	*Euonymus* sp.	Soyala K 112	Celastraceae	Liana	DIF	Root	500–1000
65	*Ficus hederacea* Roxb.	Soyala K 036	Moraceae	Liana	AR, FE, R	Root	< 500
66	*Ficus pumila* L.	Soyala K 037	Moraceae	Liana	FE, AR	Root	< 500; 1000–1500
67	*Fissistigma* sp.	Soyala K 184	Annonaceae	Liana	DIF	Twiner	< 500
68	*Gnetum montanum* Markgr.	Soyala K 101	Gnetaceae	Liana	R, DIF, DF, OF	Twiner	0–1000
69	*Gouania leptostachya* DC.	Soyala K 086	Rhamnaceae	Liana	R, AR	Tendril	0–1000
70	*Hedyotis scandens* Roxb.	Soyala K 087	Rubiaceae	Vine	AR, DIF, FE	Twiner	0–1500
71	*Hemidesmus indicus* (L.) R. Br. ex Schult.	Soyala K 136	Apocynaceae	Vine	DIF	Twiner	< 500; 1000–1500
72	*Heterosmilax japonica* Kunth	Soyala K 096	Smilacaceae	Vine	DF	Tendril	1000–1500
73	*Hodgsonia heteroclita* (Roxb.) Hook.f. & Thomson	Soyala K 065	Cucurbitaceae	Vine	FE	Tendrils	>1500
74	*Holboellia latifolia* Wall.	Soyala K 124	Berberidaceae	Liana	AR, DIF, R, OF	Twiner	< 500
75	*Holmskioldia sanguinea* Retz.	Soyala K 015	Lamiaceae	Liana	AR, WL	Rambler	< 500
76	*Hoya globulosa* Hook.f.	Soyala K 038	Apocynaceae	Liana	AR	Twiner	< 500
77	*Hoya pubicalyx* Merr.	Soyala K 130	Apocynaceae	Liana	DIF	Twiner	< 500
78	*Hydrangea anomala* D. Don	Soyala K 097	Hydrangeaceae	Liana	R	Root	>1500
79	*Ichnocarpus frutescens* (L.) W.T. Aiton	Soyala K 125	Apocynaceae	Liana	AR	Twiner	< 500
80	*Ipomoea alba* L.	Soyala K 060	Convolvulaceae	Vine	AR, WL	Twiner	< 500
81	*Ipomoea aquatica* Forssk.	Soyala K 039	Convolvulaceae	Vine	WL	Twiner	< 500
82	*Ipomoea batatas* (L.) Lam.	Soyala K 156	Convolvulaceae	Vine	AR, WL	Twiner	0–1000
83	*Ipomoea cairica* (L.) Sweet	Soyala K 042	Convolvulaceae	Vine	AR, WL	Twiner	< 500
84	*Ipomoea purpurea* (L.) Roth	Soyala K 092	Convolvulaceae	Vine	AR	Twiner	< 500
85	*Ipomoea quamoclit* L.	Soyala K 008	Convolvulaceae	Vine	AR	Twiner	< 500
86	*Ipomoea triloba* L.	Soyala K 014	Convolvulaceae	Vine	WL	Twiner	< 500

	Botanical name	Voucher no.	Family	Habit	Habitat	Climbing mode	Elevation zone (m)
87	*Jasminum laurifolium* Roxb. ex Hornem.	Soyala K 089	Oleaceae	Liana	OF	Rambler	500–1000
88	*Lagenaria siceraria* (Molina) Standl.	Soyala K 163	Cucurbitaceae	Vine	AR, FE	Tendrils	500–1500
89	*Luffa cylindrica* (L.) M.Roem.	Soyala K 009	Cucurbitaceae	Vine	AR, WL	Tendrils	< 500
90	*Lycopodium clavatum* L.	Soyala K 082	Lycopodiaceae	Vine	AR	Rambler	0–1000
91	*Lygodium flexuosum* (L.) Sw.	Soyala K 116	Lygodiaceae	Vine	AR, WL	Twiner	< 500
92	*Lygodium japonicum* (Thunb.) Sw.	Soyala K 170	Lygodiaceae	Vine	WL	Twiner	< 500
93	*Macroptilium atropurpureum* (DC.) Urb.	Soyala K 013	Fabaceae	Vine	WL	Twiner	< 500
94	*Mansoa alliacea* (Lam.) A.H. Gentry	Soyala K 040	Bignoniaceae	Liana	AR	Tendril	< 500
95	*Mastersia assamica* Benth.	Soyala K 148	Fabaceae	Liana	AR, FE, WL	Twiner	< 500
96	*Melocalamus compactiflorus* (Kurz) Benth.	Soyala K 128	Poaceae	Liana	FE	Rambler	< 500
97	*Melodinus cochinchinensis* (Lour.) Merr.	Soyala K 024	Apocynaceae	Liana	FE	Rambler	< 500
98	*Merremia umbellata* (L.) Hallier f.	Soyala K 117	Convolvulaceae	Vine	WL	Twiner	< 500
99	*Mikania micrantha* Kunth	Soyala K 095	Asteraceae	Vine	AR, DIF, FE, OF, R, WL	Twiner	All elevation zones
100	*Millettia pachycarpa* Benth.	Soyala K 143	Fabaceae	Liana	AR, DF, FE, OF	Twiner	0–1500
101	*Momordica charantia* L.	Soyala K 041	Cucurbitaceae	Vine	WL	Tendril	< 500
102	*Momordica dioica* Roxb. ex Willd.	Soyala K 061	Cucurbitaceae	Vine	R, FE	Tendril	< 500
103	*Mukia maderaspatana* (L.) M.Roem.	Soyala K 033	Cucurbitaceae	Vine	WL, R, AR	Tendril	< 500
104	*Myxopyrum smilacifolium* (Wall.) Blume	Soyala K 021	Oleaceae	Liana	FE, OF	Twiner	< 500
105	*Naravelia zeylanica* (L.) DC.	Soyala K 043	Ranunculaceae	Liana	FE, AR	Tendril	< 500
106	*Natsiatum herpeticum* Buch.-Ham. ex Arn.	Soyala K 114	Icacinaceae	Vine	AR, WL	Twiner	< 500
107	*Paederia foetida* L.	Soyala K 123	Rubiaceae	Vine	WL, R, AR	Twiner	0–1000
108	*Parthenocissus semicordata* (Wall.) Planch.	Soyala K 062	Vitaceae	Vine	R	Tendril	>1500
109	*Passiflora vitifolia* Kunth	Soyala K 154	Passifloraceae	Vine	AR	Tendril	< 500
110	*Pegia nitida* Colebr.	Soyala K 126	Anacardiaceae	Liana	AR, FE, WL	Rambler	0–1000
111	*Pericampylus glaucus* (Lam.) Merr.	Soyala K 144	Menispermaceae	Vines	FE, OF	Twiner	0–1000
112	*Periploca calophylla* (Wight) Falc.	Soyala K 063	Apocynaceae	Liana	DF, FE	Twiner	>1500
113	*Persicaria chinensis* (L.) H. Gross	Soyala K 158	Polygonaceae	Vine	AR	Rambler	0–1000
114	*Persicaria nepalensis* (Meisn.) Miyabe	Soyala K 119	Polygonaceae	Vine	AR	Rambler	< 500
115	*Philodendron hederaceum* (Jacq.) Schott	Soyala K 157	Araceae	Vine	AR, R	Root	< 500
116	*Phyllanthus reticulatus* Poir.	Soyala K 151	Euphorbiaceae	Liana	WL	Scrambler	< 500
117	*Piper acutistigmum* C.DC.	Soyala K 080	Piperaceae	Vine	FE, R	Root	0–1500
118	*Piper arunachalensis* Gajurel, Rethy & Y. Kumar	Soyala K 047	Piperaceae	Vine	FE, R	Root	500–1500
119	*Piper attenuatum* Buch.-Ham. ex Miq.	Soyala K 019	Piperaceae	Vine	AR, FE, R	Root	0–1000
120	*Piper betleoides* C.DC.	Soyala K 106	Piperaceae	Vine	AR, FE	Root	0–1500
121	*Piper griffithii* C.DC.	Soyala K 023	Piperaceae	Vine	FE	Root	< 500
122	*Piper haridasanii* Gajurel, Rethy & Y. Kumar	Soyala K 017	Piperaceae	Vine	AR, FE, R	Root	< 500
123	*Piper longum* L.	Soyala K 072	Piperaceae	Vine	AR, FE	Root	< 500
124	*Piper rhytidocarpum* Hook. f.	Soyala K 016	Piperaceae	Vine	FE, R, OF	Root	01000
125	*Piper sylvaticum* Roxb.	Soyala K 018	Piperaceae	Vine	AR, FE	Root	< 500
126	*Poikilospermum naucleiflorum* (Roxburgh ex Lindl.) Chew	Soyala K 129	Urticaceae	Liana	DF, FE	Root	0–1000
127	*Polygonum perfoliatum* L.	Soyala K 181	Polygonaceae	Vine	R, WL	Rambler	0–1000
128	*Pothos chinensis (*Raf.) Merr.	Soyala K 134	Araceae	Vine	AR, FE	Root	< 500; 1000–1500
129	*Pothos longipes* Schott	Soyala K 120	Araceae	Vine	DF, FE	Root	>1500

	Botanical name	Voucher no.	Family	Habit	Habitat	Climbing mode	Elevation zone (m)
130	*Pothos scandens* L.	Soyala K 091	Araceae	Vine	AR, DF	Root	< 500; >1500
131	*Pueraria montana* var. *lobata* (Willd.) Sanjappa & Pradeep	Soyala K 012	Fabaceae	Vine	AR, WL	Twiner	< 500
132	*Pueraria phaseoloides* (Roxb.) Benth.	Soyala K 094	Fabaceae	Vine	WL	Twiner	< 500
133	*Pyrostegia venusta* (Ker Gawl.) Miers	Soyala K 059	Bignoniaceae	Liana	AR	Tendril	< 500
134	*Pyrrosia nummulariifolia* (Sw.) Ching	Soyala K 056	Polypodiaceae	Vine	AR, DF, FE	Root	< 500
135	*Rhaphidophora decursiva* (Roxb.) Schott	Soyala K 132	Araceae	Liana	FE, DF, OF	Root	All elevation zones
136	*Rhaphidophora lancifolia* Schott	Soyala K 103	Araceae	Liana	DF, FE	Root	< 500; 1000–1500
137	*Rubia cordifolia* L.	Soyala K 135	Rubiaceae	Vine	AR, FE	Rambler	500–1500
138	*Rubia sikkimensis* Kurz	Soyala K 073	Rubiaceae	Vine	FE, AR, OF	Rambler	500–1500
139	*Rubus ellipticus* Sm.	Soyala K 139	Rosaceae	Liana	FE, AR	Scrambler	1000–1500
140	*Rubus hamiltonii* Hook.f.	Soyala K 069	Rosaceae	Liana	FE, AR,	Scrambler	1000–1500
141	*Rubus lucens* Focke	Soyala K 137	Rosaceae	Liana	FE, AR, OF	Scrambler	500–1500
142	*Rubus paniculatus* Sm.	Soyala K 098	Rosaceae	Liana	AR, FE	Scrambler	500–1500
143	*Rubus praestans* H.E. Weber	Soyala K 140	Rosaceae	Liana	FE, AR	Scrambler	500–1500
144	*Rubus rugosus* Sm.	Soyala K 164	Rosaceae	Liana	FE, AR	Scrambler	< 500
145	*Rubus sumatranus* Miq.	Soyala K 175	Rosaceae	Liana	AR	Scrambler	< 500
146	*Sabia lanceolata* Colebr.	Soyala K 083	Sabiaceae	Liana	FE	Twiner	500–1000
147	*Schefflera elliptica* (Blume) Harms	Soyala K 025	Araliaceae	Liana	AR, FE	Root	< 500
148	*Schefflera roxburghii* Gamble	Soyala K 057	Araliaceae	Liana	AR	Root	< 500
149	*Schisandra neglecta* A.C. Sm.	Soyala K 048	Schisandraceae	Liana	DF, R	Twiner	500–1000
150	*Scindapsus officinalis* (Roxb.) Schott	Soyala K 167	Araceae	Vine	OF, DF	Root	500–beyond 1500
151	*Selaginella helferi* Warb.	Soyala K 077	Selaginellaceae	Vine	AR	Rambler	0–1000
152	*Senecio scandens* Buch.-Ham. ex D.Don	Soyala K 074	Asteraceae	Vine	FE, OF	Twiner	1000–1500
153	*Shuteria involucrata* (Wall.) Wight & Arn.	Soyala K 100	Fabaceae	Vine	FE, OF	Twiner	500–1000
154	*Smilax glabra* Roxb.	Soyala K 078	Smilacaceae	Vine	FE	Tendril	500–1000
155	*Smilax lanceifolia* Roxb.	Soyala K 070	Smilacaceae	Vine	DIF	Tendril	500–1500
156	*Smilax menispermoidea* A.DC.	Soyala K 066	Smilacaceae	Vine	DF, OF	Tendril	>1500
157	*Smilax ovalifolia* Roxb. ex D.Don	Soyala K 044	Smilacaceae	Vine	FE, WL	Tendril	< 500
158	*Smilax perfoliata* Lour.	Soyala K 138	Smilacaceae	Vine	DIF, FE	Tendril	500–1500
159	*Smilax roxburghiana* Wall. ex A.DC.	Soyala K 067	Smilacaceae	Vine	DIF, FE	Tendril	1000–beyond 1500
160	*Solanum jasminoides* J. Paxton	Soyala K 104	Solanaceae	Vine	AR	Tendril	500–1000
161	*Solena heterophylla* Lour.	Soyala K 118	Cucurbitaceae	Vine	WL	Tendril	< 500
162	*Stemona tuberosa* Lour.	Soyala K 030	Stemonaceae	Vine	AR, R	Twiner	0–1000
163	*Stephania glabra* (Roxb.) Miers	Soyala K 186	Menispermaceae	Vine	AR, FE	Twiner	0–1000
164	*Stephania glandulifera* Miers	Soyala K 033	Menispermaceae	Vine	AR, FE, R	Twiner	< 500
165	*Stephania japonica* (Thunb.) Miers	Soyala K 034	Menispermaceae	Vine	WL	Twiner	< 500
166	*Stephania rotunda* Lour.	Soyala K 187	Menispermaceae	Vine	WL	Twiner	< 500
167	*Syngonium neglectum* Schott	Soyala K 033	Araceae	Vine	AR, WL	Root	< 500
168	*Tetracera sarmentosa* (L.) Vahl	Soyala K 034	Dilleniaceae	Liana	R, WL, OF	Twiner	< 500
169	*Tetrastigma bracteolatum* (Wall.) Planch.	Soyala K 111	Vitaceae	Liana	FE	Tendrils	500–1000
170	*Tetrastigma pubinerve* Merr. & Chun	Soyala K 068	Vitaceae	Liana	DF, FE	Tendril	< 500; >1500
171	*Tetrastigma rumicispermum* (M.A. Lawson) Planch.	Soyala K 076	Vitaceae	Liana	DF, FE, R, OF	Tendril	500–1500
172	*Tetrastigma serrulatum* (Roxb.) Planch.	Soyala K 147	Vitaceae	Liana	DIF, OF	Tendril	< 500
173	*Thladiantha cordifolia* (Blume) Cogn.	Soyala K 035	Cucurbitaceae	Vine	AR, DIF	Tendril	< 500

	Botanical name	Voucher no.	Family	Habit	Habitat	Climbing mode	Elevation zone (m)
174	*Thunbergia alata* Bojer ex Sims	Soyala K 160	Acanthaceae	Vine	AR, WL	Twiner	< 500
175	*Thunbergia coccinea* Wall.	Soyala K 058	Acanthaceae	Vine	FE, R, DIF	Twiner	0–1000
176	*Thunbergia fragrans* Roxb.	Soyala K 141	Acanthaceae	Vine	AR, WL	Twiner	< 500
177	*Thunbergia grandiflora* (Roxb. ex Rottl.) Roxb.	Soyala K 026	Acanthaceae	Vine	FE, WL, DIF, AR	Twiner	0–1000
178	*Tinospora sinensis* (Lour.) Merr.	Soyala K 093	Menispermaceae	Vine	R, FE	Twiner	0–1000
179	*Toddalia asiatica* (L.) Lam.	Soyala K 168	Rutaceae	Liana	FE, DF	Scrambler	500–1500
180	*Trichosanthes dioica* Roxb.	Soyala K 054	Cucurbitaceae	Vine	WL	Tendril	500–1000
181	*Trichosanthes tricuspidata* Lour.	Soyala K 185	Cucurbitaceae	Vine	AR, FE	Tendrils	0–1000
182	*Trichosanthes wallichiana* (Ser.) Wight	Soyala K 084	Cucurbitaceae	Vine	FE, OF	Tendril	500–1000
183	*Tropaeolum majus* L.	Soyala K 022	Tropaeolaceae	Vine	WL, R	Twiner	0–1000
184	*Uncaria sessilifructus* Roxb.	Soyala K 166	Rubiaceae	Liana	FE, DF	Scrambler	500–1500
185	*Vernonia* sp.	Soyala K 071	Asteraceae	Vine	FE	Rambler	1000–1500
186	*Vigna umbellata* (Thunb.) Ohwi & H.Ohashi	Soyala K 178	Fabaceae	Vine	AR, WL	Twiner	< 500
187	*Volkameria inermis* L.	Soyala K 010	Lamiaceae	Liana	WL	Rambler	0–1000

DF—Dense Forest I OF—Open Forest I DIF—Disturbed Forest I FE—Forest Edge I R—Riverine areas I WL—Wastelands I AR—Areas along roadsides I EAP—Endemic to Arunachal Pradesh I ENE—Endemic to northeastern region I EEH—Endemic to Eastern Himalaya.

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Image 1. A—*Crawfurdia campanulacea* I B—*Dioscorea oppositifolia* I C—*Melodinus cochinchinensis* I D—*Pegia nitida* I E—*Phyllanthus reticulatus* I F—*Pericampylus glaucus* | G—*Hedyotis scandens* I H—*Holboellia latifolia* I I—*Dalhousiea bracteata* I J—*Uncaria sessilifructus* (hook) I K—*Croton caudatus* (twiner) I L—*Smilax menispermoidea* (tendril). © Soyala Kashung and P.R. Gajurel.

Image 2. A—*Piper arunachalensis* I B—*Decalepis khasiana* I C—*Gnetum montanum* I D—*Rubia sikkimensis* I E—*Shuteria involucrata* I F—*Cissampelopsis volubilis* I G—*Embelia floribunda* I H—*Argyreia nervosa* I I—*Myxopyrum smilacifolium* I J—*Natsiatum herpeticum* I K—*Smilax glabra* I L—*Mukia maderaspatana*. © Soyala Kashung and P.R. Gajurel.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17984–17989
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.3670.13.3.17984-17989
#3670 | Received 28 March 2020 | Final received 09 February 2021 | Finally accepted 19 February 2021
PLATINUM OPEN ACCESS
SHORT COMMUNICATION

Occurrence of mammalian small carnivores in Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India

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Abstract: The small mammalian carnivores are important for maintaining healthy ecosystems. The present documentation is based on the camera trap survey in Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu. Paired camera-traps were set in a grid of 1.413 × 1.413 km area of 180km² within an altitudinal range of 80–1,866 m. A total of 11 species were recorded in different habitat types. Brown Palm Civet *Paradoxurus jerdoni* and Leopard Cat *Prionailurus bengalensis* had the highest capture rates and the lowest was Rusty Spotted Cat *Prionailurus rubiginosus*.

Keywords: Camera trapping, KMTR, lesser carnivores, smaller mammals.

Small carnivores are difficult to study due to their elusive, small, (semi-) arboreal, and crepuscular or nocturnal habits (Mudappa 2001). Extensive camera-trapping of carnivores across India has provided some published information on small carnivores, with a few systematic surveys specifically for them. Camera-trapping surveys in other protected areas provided important data on some species of small carnivores (Datta et al. 2008; Nixon et al. 2010; Gupta 2011; Prakash et al. 2012). The Western Ghats mountain range in India is a global biodiversity hotspot with a high diversity of plant and animal taxa (Myers et al. 2000), including small carnivores. The Western Ghats, with an estimated four-fold increase in the number of forest fragments and an 83% reduction in the size of surviving patches between 1920 and 1990, and a very high human population density, is critically threatened by habitat degradation and fragmentation (Menon & Bawa, 1997; Menon 2003). The rainforests of the Western Ghats have six species of non-aquatic small carnivores including two endemic species (Nilgiri Marten *Martes gwatkinsii*, Brown Palm Civet *Paradoxurus jerdoni*), two endemic sub-species which otherwise also occur in Sri Lanka (Stripe-necked Mongoose *Herpestes vitticollis*, Brown Mongoose *H. fuscus*), and two geographically very widespread species (Small Indian Civet *Viverricula indica*, Leopard Cat *Prionailurus bengalensis*) (Ramesh et al. 2012).

The Western Ghats offer a wide range of habitats from lowland scrub forests to rainforests at high elevations, supporting many species of small carnivores. Mudappa (2001) and Mudappa et al. (2007) reported the small carnivore composition in part of the Agasthyamalai landscape of Kalakad-Mundanthurai Tiger Reserve (KMTR) using opportunistic sight records, sign surveys, live trapping, and radio-telemetry. The present study reports small carnivores in KMTR based on camera trap surveys and opportunistic sight records.

Editor: Honnavalli N. Kumara, Salim Ali Centre for Ornithology and Natural History, Coimbatore, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Venkatesh, A., N. Sridharan, S.A.J. Packiavathi & K.M. Selvan (2021). Occurrence of mammalian small carnivores in Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. *Journal of Threatened Taxa* 13(3): 17984–17989. https://doi.org/10.11609/jott.3670.13.3.17984-17989

Funding: Kalakad Mundanthurai Tiger Conservation Foundation.

Competing interests: The authors declare no competing interests.

Acknowledgements: Our sincere thanks to Principal Chief Conservator of Forests & Chief Wildlife Warden, Tamil Nadu for granting permission to carryout intensive study in KMTR. We would like to thank Kalakad Mundanthurai Tiger Conservation Foundation, Officials and field staff of KMTR for the logistic support extended in the field.

Study Area

The Kalakad-Mundanthurai Tiger Reserve is located in the southern part of the Western Ghats of India. This region forms one of the important bio-diversity 'hotspots'(Ganesh et al. 1996; Ramesh et al. 1997; Myers et al. 2000; Johnsingh 2001) and is recognized as Type-1 Tiger Conservation Unit (Wikramanayake et al. 1998), due to its large and contiguous forested tracts. The reserve is spread over an area of 895km^2 and located between 7.16—77.58 ^{0}E & 8.41–8.83 ^{0}N (Figure 1). The altitude varies from 60m to 1,866m characterized by hilly terrain with low and high altitude plateau. It receives both the south-west and north-east monsoons with mean annual rainfall of over 3,200mm. Mean monthly temperature ranges 15–30 °C. Besides three large carnivores, KMTR harbors several prey species such as Sambar *Rusa unicolor*, Gaur *Bos gaurus*, Chital *Axis axis*, Wild Boar *Sus scrofa*, Barking Deer *Muntiacus muntjak*, Indian Chevrotain *Tragulus meminna*, Asian Elephant *Elephas maximus*, Black-naped Hare *Lepus nigricollis*, Bonnet Macaque *Macaca radiata*, Common Langur *Semnopithecus priam*, Lion-tailed Macaque *Macaca silenus*, Nilgiri Tahr *Hemitragus hylocrius*, Indian Porcupine *Hysterix indica*, Indian Giant Squirrel *Ratufa indica*, Grey Jungle Fowl *Gallus sonneratii*, Red Spur Fowl *Galloperdix spadicea* and Indian Peafowl *Pavo cristatus* (Johnsingh 2001). Major forest types include the southern hill top evergreen, southern tropical wet evergreen, Tirunelveli semi-evergreen, southern moist mixed deciduous, tropical riparian fringe, dry teak, southern dry mixed deciduous, Carnatic umbrella thorn, Ochlandra reeds, southern montane wet temperate forests, and grasslands of low and high altitudes (Champion & Seth 1968).

Methods

Field survey

An area of 180km² within the altitudinal range of 80–1,866 m had three intensive camera-trapping zones, in deciduous & thorn forest (84km²) and tropical rain forest (96km²), from 09 April to 23 May 2015 (Image 1a&b). All the forest types had been surveyed during the dry season. Paired camera-traps were set in a grid of 1.413 × 1.413 km. Each station had two independently operating passive-infrared cameras (Cudde back Attack; Cudde back C3) mounted, opposite each other on trails,

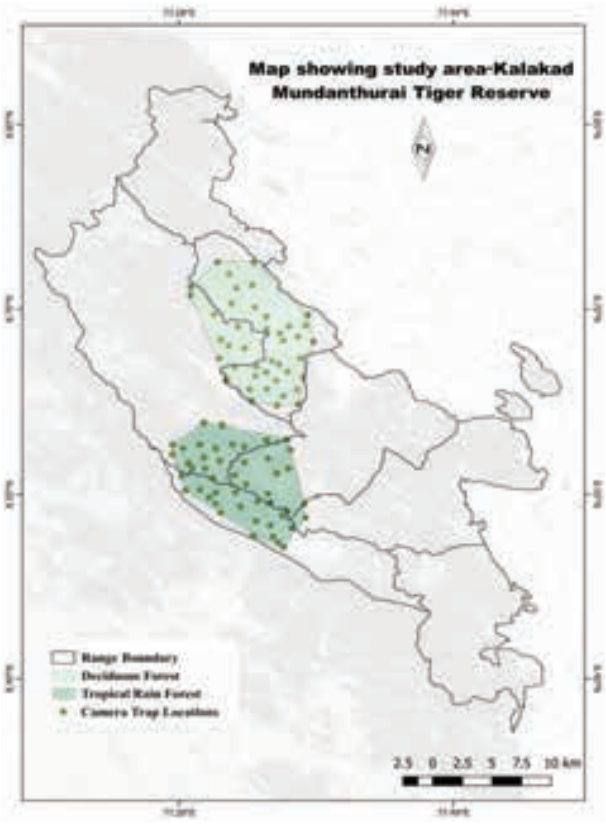

Figure 1. Camera trap locations in the study area of Kalakad-Mundanthurai Tiger Reserve

Figure 2. Species capture details in the study area.

Image 1 Study area. a—tropical riparian fringe forest | b—southern tropical wet evergreen forests. © S. Agnes

dirt roads, stream beds, termite mounds, and fresh animal carcases; and in other locations with evidence of small carnivore movement. Camera-traps were active for 24 hours a day, without bait or lure. The latency after each photograph was set to 1minute and sensitivity was set to high. Camera-traps were set approximately 25cm above ground (targeting civets). All camera-traps were checked, on an average, every three days. Each camera trap pair were given an unique ID, memory card ID, location names, GPS-derived co-ordinates, habitat descriptions, set-up and removal dates, and presence of animal signs were recorded for each camera-trap site. Additional information was compiled from sign surveys, interviews with locals and frontline staff, and also based on opportunistic drives during day and night using a four-wheeler at a speed of 15 km/h to look for small carnivores.

Data analysis

Each photograph was recorded with date and time. A photographic event, in camera-traps at a single camera station was considered notionally independent if it was at least 10 minutes after the species' preceding image at that station. Detections involving more than one individual, but part of the same social unit, e.g., mother and young, were counted as a single event. Encounter rates were derived by dividing the number of notionally independent events by the camera-trap-nights × 100.

Results

A total of 3,510 trap-nights yielded 187 notionally independent photographs of 11 species namely: Jungle Cat *Felis chaus*, Leopard Cat *Prionailurus bengalensis*, & Rusty-spotted Cat *P. rubiginosus* (27 notionally independent photographs), Small Indian Civet *Viverricula indica* (46), Common Palm Civet (one), Brown Palm Civet (76), Stripe-necked Mongoose *Herpestes vitticollis* (10), Brown Mongoose *H. fuscus* (nine), and Ruddy Mongoose *H. smithii* (eight) (Table 1, Image 2a–i, Figure 2). Smooth-coated Otter *Lutrogale perspicillata* was not camera-trapped, but was sighted opportunistically.

Species Accounts

Smooth-coated Otter *Lutrogale perspicillata*

In 2015, two otters were sighted at around 11.30h, observed for 20 minutes, in the evergreen forests of Upper Kodayar dam site, Upper Kodayar range. Likewise, a group of otters with six individuals was sighted in the lower dam area of Papanasam range in deciduous forest. Tracks, specifically in moist mud and spraints were often observed in both the forest types. The spraint consisted of crushed crabs, shells and fish remains, deposited over rocks along the banks of perennial water bodies (large and small), and sometimes along the forest trails close to these water bodies.

Small Indian Civet *Viverricula indica*

The Small Indian Civet was recorded at 30.76% of all camera-trap locations in both the forest types. It was sighted during the night survey in Mundanthurai plateau. All photographs were obtained between dusk and dawn (18.00–06.00 h). Capture rate was higher in the tropical rain forest (1.76) than in the deciduous forest (0.59).

Common Palm Civet *Paradoxurus hermaphrodites*

The Common Palm Civet was recorded at 1.28 % of all camera-trap locations. Encounter rates were recorded only in the deciduous forest and none recorded in the tropical rain forest. During night drives, the animal was observed in deciduous forest. It was photographed between 18.00h and 05.00h.

Table1. Number of camera-trap stations with records (CS), notionally independent photo-captures (NIPC) and capture rate CR (NIPC/100 trap nights) of small carnivores in Kalakad-Mundanthurai Tiger Reserve, India (2015).

	Species	Deciduous forests			Tropical rainforests		
		CS	NIPC	ER	CS	NIPC	ER
1	Leopard Cat				12	23	1.06
2	Small Indian Civet	5	8	0.59	19	38	1.76
3	Brown Palm Civet				20	76	3.52
4	Ruddy Mongoose	7	8	0.59			
5	Stripe necked Mongoose				8	10	0.46
6	Nilgiri Marten				3	8	0.37
7	Brown Mongoose				8	9	0.42
8	Rusty Spotted cat	1	1	0.07			
9	Common Palm civet	1	1	0.07			
10	Smooth Coated otter				1	2	0.09
11	Jungle Cat	2	3	0.22			

Brown Palm Civet *Paradoxurus jerdoni*

The Brown Palm Civet was photographed only in tropical rain forests, being recorded in 25.64% of all camera-trap locations. All photographs were obtained during night hours (23.00–03.45 h).

Stripe-necked Mongoose *Herpestes vitticollis*

The Stripe-necked Mongoose was photographed in 12.82% of all camera-trap stations. During night surveys very often it was recorded in deciduous forest.

Brown Mongoose *Herpestes fuscus*

The Brown Mongoose was photographed in 10.25% of all camera-trap stations of tropical rain forests during day time.

Ruddy Mongoose *Herpestes smithii*

The Ruddy Mongoose was camera-trapped most often in the open habitats of deciduous and thorn forests amounting to 10.25% of all camera trapping sites. None was recorded in the tropical rain forest.

Leopard Cat *Prionailurus bengalensis*

The Leopard Cat was photographed in 10.16% of camera-trap stations with a capture rate of 0.17. Totally 13 individuals have been identified based on the unique spots from 23 photos. It was photographed at 18.00–06.00 h. In 2015, two individuals were sighted during field survey (19.33h & 19.17h) in the upper Kodayar.

Rusty Spotted cat *Prionailurus rubiginosus*

The Rusty Spotted Cat has a relatively restricted distribution in KMTR. In the entire camera trapping session for 45 days, the species was camera-trapped only once in deciduous forest and the encounter rate was 0.03.

Nilgiri Marten

The Nilgiri Marten was captured in four camera trap locations of tropical rain forest at altitudes varying 1,300–1,800 m.

Discussion

KMTR with its diverse forest types is inhabited by many species of smaller carnivores as evidenced in this study. Seven species were recorded in the tropical rain forest through camera trap and direct sighting and four species were recorded in the deciduous forests. Among the former seven species, the Brown Palm Civet showed the highest encounter rate followed by Small Indian Civet, Leopard Cat, and Brown Mongoose. The Brown Palm Civet has been recorded only in the evergreen forests occurring in both little-disturbed, large contiguous forests as well as fragments surrounded by tea plantations and/or human habitations (Mudappa 2001; Rajamani et al. 2002).

Forest type has been observed to influence the distribution of the Brown Palm Civet, with the species being more common in evergreen forests at altitudes above 900m. Nevertheless, the higher capture rates indicating higher abundances in KMTR are probably sustained by the higher forage species densities in the relatively undisturbed rainforests, particularly species such as *Palaquium ellipticum*, *Holigarna nigra*,

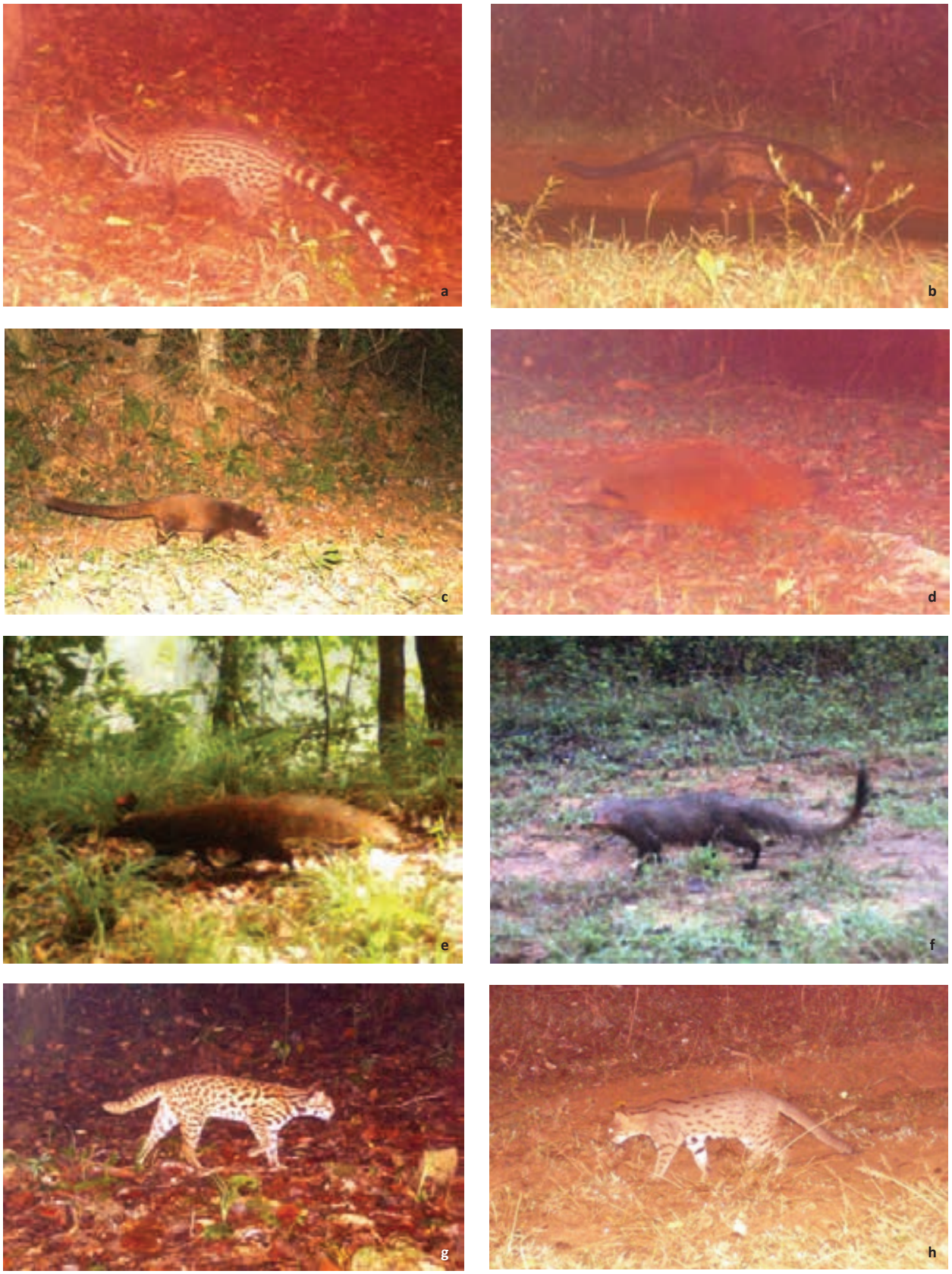

Image 2. a—Small Indian Civet *Viverricula indica* | b—Common Palm Civet *Paradoxurus hermaphrodites* | c—Brown Palm Civet *Paradoxurus jerdoni* | d—Stripe-necked Mongoose *Herpestes vitticollis* | e— Brown Mongoose *Herpestes fuscus* | f— Ruddy Mongoose *Herpestes smithii* | g—Leopard Cat *Prionailurus bengalensis* | h—Rusty-spotted Cat *Prionailurus rubiginosus*. © N. Sridharan

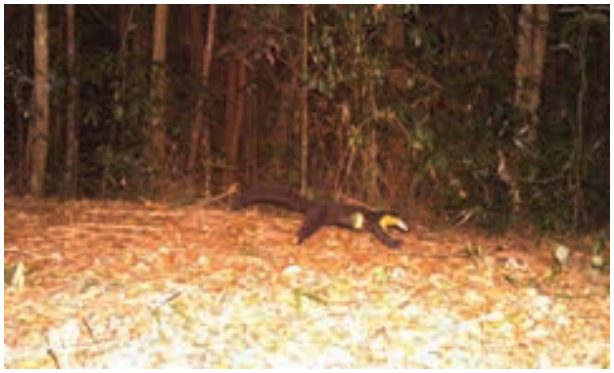

Image 2i— Nilgiri Marten *Martes gwatkinsii*. © KMTR

Elaeocarpus spp., *Ficus* spp., *Acronychia pedunculata,* and *Gnetum ula* (Mudappa 2001). The endemic Brown Palm Civet, is an important frugivore and seed-disperser in these rainforests and one of the species with the smallest distribution range among southern Asian carnivores. KMTR with its large tract of relatively undisturbed rainforests is potentially one of the most significant areas for the long-term conservation of small carnivores in the Western Ghats.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17990–17998
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.4769.13.3.17990-17998
#4769 | Received 15 November 2019 | Final received 19 July 2020 | Finally accepted 27 February 2021
PLATINUM OPEN ACCESS
SHORT COMMUNICATION

Changed avian assemblage of Savitribai Phule Pune University campus in last four decades

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Abstract: Savitribai Phule Pune University is known for its biodiversity in Pune. In the present study, we have analyzed changes which have occurred on the campus and surrounding area over the last 40 years. Of the 90 bird species reported in the campus and Khadki pond in 1976, we failed to notice 34 species in 2018. A major reason for the decline in bird diversity could be changes in the campus habitat from low scrub jungle, fallow lands and grassland to buildings, roads, and exotic plantations. Increase in human settlement surrounding the campus may also be a contributing factor. Replacing exotic plants by indigenous plant species and control of land use can prevent further loss of biodiversity.

Keywords: Educational campus, exotic plants, urbanization, loss of native flora.

Cities are under the pressure of anthropogenic activities such as the construction of roads, buildings, industries, increased human settlement, and pollution. Most of the cities in the world are established in biodiversity rich regions. As anthropogenic pressure increases in the cities, people start intruding into naturally balanced ecosystems surrounding them. Increase in the human population and anthropogenic activities affect the diversity and structure of biological communities (Vitousek 1994; Maurer 1996). Urbanization causes long term loss of native habitats (Simberloff 1986) and creates human-specific environments (McKinney 2002). Though anthropogenic disturbance is great within in cities, some places such as campuses of educational institutes are comparatively less disturbed and more rich in biodiversity. The biodiversity of many educational institutes is well documented, making them good places to study changes in biodiversity over time. We noticed an increase in anthropogenic activities in the campus of Savitribai Phule Pune University (SPPU) when consultation of previous floral literature for Ganeshkhind (the surrounding region; Varadpande 1973) indicated drastic changes in vegetation. Grassland-scrub vegetation and fallow land in the campus was diminished, replaced with buildings, roads and exotic plantations. Birds are good indicators of biodiversity change due to their sensitivity to environmental changes (Gregory 2006). In this study, we analyzed the impact of vegetation change and anthropogenic activities on avian diversity of Savitribai Phule Pune University campus and Khadki pond.

Editor: S. Subramanya, University of Agriculture Sciences, Bengaluru, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Choudaj, K. & V. Wankhade (2021). Changed avian assemblage of Savitribai Phule Pune University campus in last four decades. *Journal of Threatened Taxa* 13(3): 17990–17998. https://doi.org/10.11609/jott.4769.13.3.17990-17998

Funding: Kiran Choudaj is a recipient of CSIR-UGC NET Junior Research Fellowship (University Grants Commission F.16-6 (DEC.2016)/2017(NET)).

Competing interests: The authors declare no competing interests.

Acknowledgements: Our special thanks to Sammer Bajaru for his assistance in GIS. We are grateful to the Estate office, Savitribai Phule Pune University, for permitting us to conduct a study on the university campus.

Material and Methods

Study area

The study was carried out in Savitribai Phule Pune University campus (18.553^0 & 73.824^0) and Khadki pond (18.555^{0}N & 73.831^{0}E) which is adjacent to the university campus. The campus is spread over 411 acres of land and contains buildings, gardens, exotic plantations, agricultural land and a university pond (Image 1). The major area of the campus is under the cover of exotic plantations; *Dalbergia melanoxylon* (African Blackwood) and *Gliricidia sepium* (Gliricidia) are two dominant exotic plant species in the campus. Alice garden is the oldest garden in the campus, containing native and non-native tree species such as *Ficus benghalensis*, *Albizia saman*, *Syzygium cumini*, *Mangifera indica*, *Polyalthia longifolia*, *Eucalyptus citriodara*, *Kigelia pinnata*, *Putranjiva roxburghii*, *Delonix regia*, and *Peltophorum pterocarpum*. Agricultural land in the campus is mostly fallow in recent days, with some utilized for horticulture. The university pond is small and seasonal, containing plant species such as *Hydrilla* sp., *Ceratophyllum* sp., *Typha* sp., *Ipomoea aquatica*, *Spirogyra* sp., *Chara* sp., *Hydrodictyon* sp. (Kulkarni et al. 2015). Khadki pond is a seasonal waterbody spread over 7.42 acres.

Data collection

We surveyed the complete area previously sampled by Goel (1976). Bird survey was carried for one and a half years, from November 2014 to April 2015 and July 2017 to June 2018. Bird survey was carried out in all three seasons (Monsoon, winter, and summer) and the complete study area was surveyed at least once per season. Other than regular surveys, opportunistic birds seen were also considered for preparing a checklist. Bird surveys were carried out by a single observer in the between 07.00h and 11.00h. Birds were observed using binoculars (Olympus 10 × 50X magnification). Audiovisual cues were used for bird identification. For identification of birds, feeding guild and residential status we used field guides of Grimmett et al. (1999), Ali (2002), and Kazmierczak & Perlo (2000). For bird taxonomy and nomenclature, we followed Praveen et al. (2016).

Results

In 1976, Goel listed 91 bird species for the university campus and nearby area of Khadki pond. From this checklist we observed only 56 species in the current survey. *Gallus gallus domesticus* (Linnaeus, 1758), a domestic fowl, is not listed in the checklist of birds of India prepared by Praveen et al. (2016), thus we considered only 90 bird species from the previous checklist when preparing a new one. In addition to the previous checklist, we found 16 new bird species in the campus, making a total of 106 bird species listed from Savitribai Phule Pune University campus and Khadki

Image 1. Savitribai Phule Pune University campus and Khadki pond, Pune.

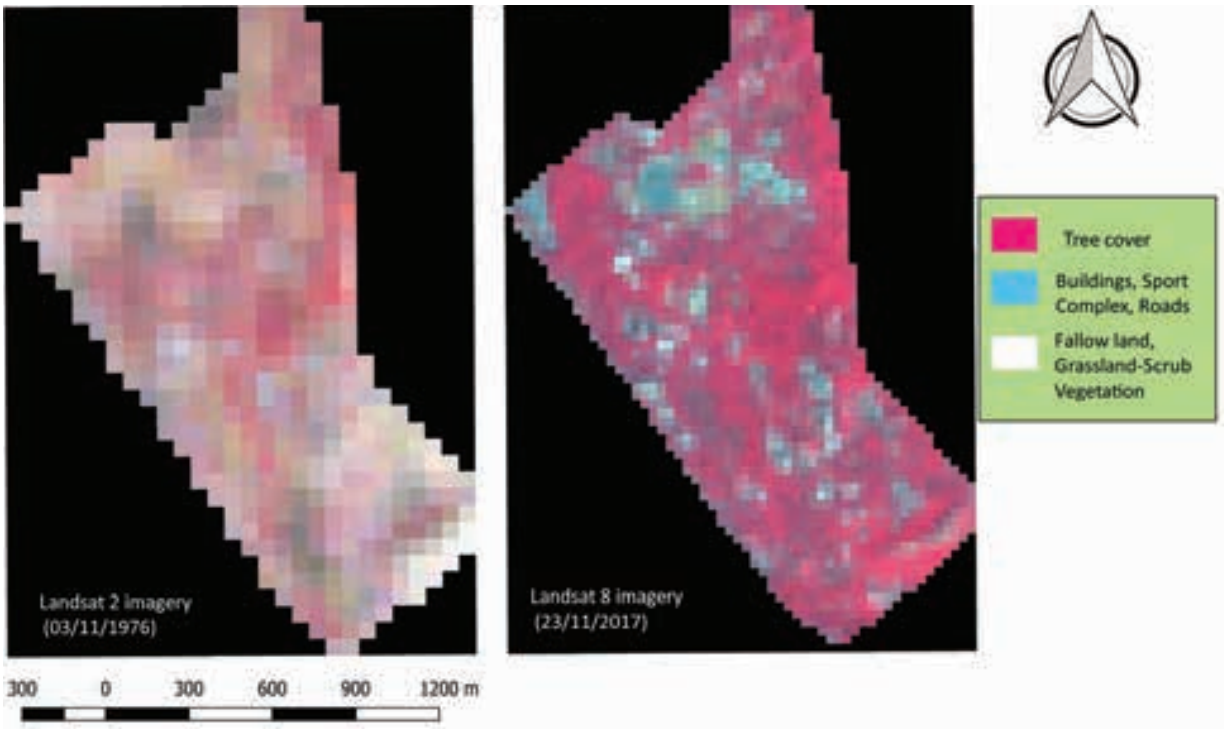

Image 2. False colour satellite imageries of Savitribai Phule Pune University campus of two time periods 1976 and 2017.

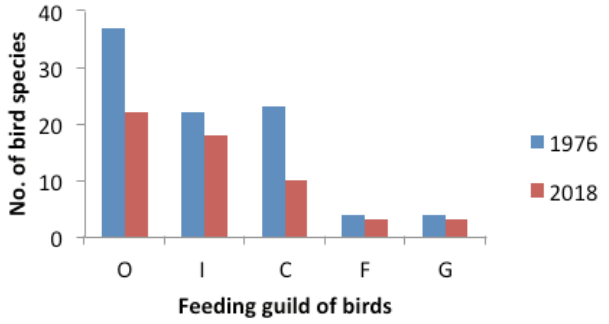

Figure 1. Feeding guild-wise decline in number of bird species of Savitribai Phule Pune University campus and Khadki pond. O—Omnivore | I—Insectivore | C—Carnivore | F—Frugivore | G—Granivore.

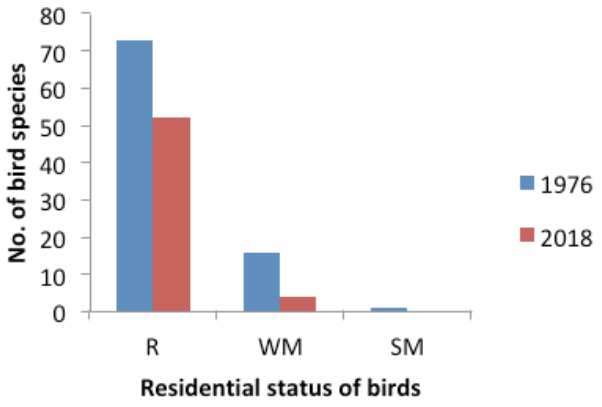

Figure 2. Residential status wise decline in number of bird species of Savitribai Phule Pune University campus and Khadki pond. R—Resident | WM—Winter migratory | SM—Summer migratory.

pond. All the birds observed are classified into 17 orders and 53 families, of which 56% birds belonged to order Passeriformes (Table 1 & 2). The richness of insectivore, carnivore and omnivore birds has declined more compared to frugivore and granivore birds (Figure 1, Table 1). The richness of both resident and migratory birds has decreased compared to 1976 (Figure 2, Table 1).

Discussion

In 1976, 17% of the entire area of university campus was occupied by buildings, roads, and gardens, the major part of rest of the area was thinly wooded low scrub jungle interspersed with various trees (Goel 1976). There were also fallow lands, three patches of trees, flower nursery and citrus garden. But thinly wooded low scrub jungle, fallow lands, flower nursery, citrus garden are no longer found on the campus, where a majority of the total area is covered with buildings, sports complexes, roads and exotic plantations (Image 2). Currently it is noted that there has been increase in buildings, sports complexes, concrete fence and

Table 1. List of avifauna recorded in the campus of Savitribai Phule Pune University and Khadki pond in 1976 and its present status in 2018.

	Order/Family/Scientific name	Common name	Food habit/ Guild	Residential status	Present status
	Phoenicopteriformes: Podicipedidae				
1	*Tachybaptus ruficollis* (Pallas, 1764)	Little Grebe	C	R	×
	Columbiformes: Columbidae				
2	*Columba livia* (J.F. Gmelin, 1789)	Rock Pigeon	G	R	_
3	*Streptopelia chinensis* (Scopoli, 1786)	Spotted Dove	G	R	×
4	*Streptopelia senegalensis* (Linnaeus, 1766)	Laughing Dove	G	R	_
5	*Treron phoenicopterus* (Latham, 1790)	Yellow-legged Green Pigeon	F	R	×
	Caprimulgiformes: Apodidae				
6	*Cypsiurus balasiensis* (J.E. Gray, 1829)	Asian Palm Swift	I	R	_
7	*Apus affinis* (J.E. Gray, 1830)	Indian House Swift	I	R	_
	Cuculiformes: Cuculidae				
8	*Centropus sinensis* (Stephens, 1815)	Greater Coucal	C	R	_
9	*Clamator jacobinus* (Boddaert, 1783)	Pied Cuckoo	C	SM	×
10	*Eudynamys scolopaceus* (Linnaeus, 1758)	Asian Koel	O	R	_
11	*Cacomantis merulinus* (Scopoli, 1786)	Plaintive Cuckoo	C	WM	×
12	*Hierococcyx varius* (Vahl, 1797)	Common Hawk Cuckoo	O	R	×
	Gruiformes: Rallidae				
13	*Amaurornis phoenicurus* (Pennant, 1769)	White-breasted Waterhen	O	R	_
	Pelecaniformes :Ardeidae				
14	*Ardeola grayii* (Sykes, 1832)	Indian Pond Heron	C	R	_
15	*Bubulcus ibis* (Linnaeus, 1758)	Cattle Egret	C	R	_
	Charadriiformes : Charadriidae				
16	*Charadrius dubius* (Scopoli, 1786)	Little Ringed Plover	C	R	×
17	*Vanellus indicus* (Boddaert, 1783)	Red-wattled Lapwing	C	R	_
18	*Vanellus malabaricus* (Boddaert, 1783)	Yellow-wattled Lapwing	C	R	×
	Rostratulidae				
19	*Rostratula benghalensis* (Linnaeus, 1758)	Greater Painted-snipe	O	R	×
	Jacanidae				
20	*Hydrophasianus chirurgus* (Scopoli, 1786)	Pheasant-tailed Jacana	O	R	×
	Scolopacidae				
21	*Tringa glareola* (Linnaeus, 1758)	Wood Sandpiper	C	WM	×
22	*Actitis hypoleucos* (Linnaeus, 1758)	Common Sandpiper	C	WM	×
23	*Tringa nebularia* (Gunnerus, 1767)	Common Greenshank	C	WM	×
24	*Gallinago gallinago* (Linnaeus, 1758)	Common Snipe	C	WM	×
	Turnicidae				
25	*Turnix suscitator* (J.F. Gmelin, 1789)	Barred Buttonquail	O	R	×
	Accipitriformes: Accipitridae				
26	*Accipiter badius* (J.F. Gmelin, 1788)	Shikra	C	R	_
27	*Milvus migrans* (Boddaert, 1783)	Black Kite	C	R	_
	Strigiformes: Strigidae				
28	*Athene brama* (Temminck, 1821)	Spotted Owlet	C	R	_
	Bucerotiformes: Bucerotidae				
29	*Ocyceros birostris* (Scopoli, 1786)	Indian Grey Hornbill	O	R	_

	Order/Family/Scientific name	Common name	Food habit/ Guild	Residential status	Present status
	Upupidae				
30	*Upupa epops* (Linnaeus, 1758)	Common Hoopoe	I	R	_
	Piciformes: Picidae				
31	*Dendrocopos mahrattensis* (Latham, 1801)	Yellow-fronted Pied Woodpecker	I	R	_
	Ramphastidae				
32	*Psilopogon haemacephalus* (Statius Muller, 1776)	Coppersmith Barbet	F	R	_
	Coraciiformes: Meropidae				
33	*Merops orientalis* (Latham, 1801)	Green Bee-eater	I	R	_
	Coraciidae				
34	*Coracias benghalensis* (Linnaeus, 1758)	Indian Roller	C	R	×
	Alcedinidae				
35	*Halcyon smyrnensis* (Linnaeus, 1758)	White-throated Kingfisher	C	R	_
	Falconiformes: Falconidae				
36	*Falco tinnunculus* (Linnaeus, 1758)	Common Kestrel	C	R	×
	Psittaciformes: Psittaculidae				
37	*Psittacula cyanocephala* (Linnaeus, 1766)	Plum-headed Parakeet	G, F	R	_
38	*Psittacula krameri* (Scopoli, 1769)	Rose-ringed Parakeet	G, F	R	_
	Passeriformes: Campephagidae				
39	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	Small Minivet	I	R	_
40	*Coracina javensis* (Horsfield, 1821)	Large Cuckooshrike	O	R	×
	Vangidae				
41	*Tephrodornis pondicerianus* (J.F. Gmelin, 1789)	Common Woodshrike	I	R	×
	Oriolidae				
42	*Oriolus oriolus* (Linnaeus, 1758)	Eurasian Golden Oriole	O	R	_
	Aegithinidae				
43	*Aegithina tiphia* (Linnaeus, 1758)	Common Iora	I	R	_
	Dicruridae				
44	*Dicrurus macrocercus* (Vieillot, 1817)	Black Drongo	O	R	_
	Laniidae				
45	*Lanius vittatus* (Valenciennes 1826)	Bay-backed Shrike	C	R	×
46	*Lanius schach* (Linnaeus, 1758)	Long-tailed Shrike	C	R	_
	Corvidae				
47	*Dendrocitta vagabunda* (Latham, 1790)	Rufous Treepie	O	R	_
48	*Corvus splendens* (Vieillot, 1817)	House Crow	O	R	_
49	*Corvus macrorhynchos* (Wagler, 1827)	Large-billed Crow	O	R	_
	Nectariniidae				
50	*Leptocoma zeylonica* (Linnaeus, 1766)	Purple-rumped Sunbird	O	R	_
51	*Cinnyris asiaticus* (Latham, 1790)	Purple Sunbird	O	R	_
	Ploceidae				
52	*Ploceus philippinus* (Linnaeus, 1766)	Baya Weaver	O	R	_
	Estrildidae				
53	*Euodice malabarica* (Linnaeus, 1758)	Indian Silverbill	G	R	_
54	*Lonchura punctulata* (Linnaeus, 1758)	Scaly-breasted Munia	O	R	_

	Order/Family/Scientific name	Common name	Food habit/ Guild	Residential status	Present status
	Passeridae				
55	*Passer domesticus* (Linnaeus, 1758)	House Sparrow	O	R	_
	Motacillidae				
56	*Anthus rufulus* (Vieillot, 1818)	Paddyfield Pipit	I	R	×
57	*Motacilla cinerea* (Tunstall, 1771)	Grey Wagtail	I	WM	_
58	*Motacilla citreola* (Pallas, 1776)	Citrine Wagtail	I	WM	×
59	*Motacilla alba* (Linnaeus, 1758)	White Wagtail	I	WM	_
60	*Motacilla maderaspatensis* (J.F. Gmelin, 1789)	White-browed Wagtail	I	R	_
61	*Motacilla flava* (Linnaeus, 1758)	Western Yellow Wagtail	I	WM	_
	Fringillidae				
62	*Erythrina erythrina* (Pallas, 1770)	Common Rosefinch	O	WM	×
	Paridae				
63	*Parus cinereus* (Vieillot, 1818)	Cinereous Tit	O	R	_
64	*Machlolophus xanthogenys* (Vigors, 1831)	Black-lored Tit	O	R	×
	Sylviidae				
65	*Sylvia hortensis* (Gmelin, 1789)	Western Orphean Warbler	O	WM	×
66	*Curruca curruca* (Linnaeus, 1758)	Lesser Whitethroat	O	WM	×
	Alaudidae				
67	*Ammomanes phoenicura* (Franklin, 1831)	Rufous-tailed Lark	O	R	×
68	*Eremopterix griseus* (Scopoli, 1786)	Ashy-crowned Sparrow Lark	O	R	×
69	*Mirafra erythroptera* (Blyth, 1845)	Indian Bushlark	O	R	×
	Cisticolidae				
70	*Prinia socialis* (Sykes, 1832)	Ashy Prinia	I	R	_
71	*Prinia inornata* (Sykes, 1832)	Plain Prinia	O	R	_
72	*Orthotomus sutorius* (Pennant, 1769)	Common Tailorbird	O	R	_
	Hirundinidae				
73	*Cecropis daurica* (Laxmann, 1769)	Red-rumped Swallow	I	R	_
74	*Hirundo smithii* (Leach, 1818)	Wire-tailed Swallow	I	R	_
75	*Ptyonoprogne rupestris* (Scopoli, 1769)	Eurasian Crag Martin	I	WM	_
76	*Ptyonoprogne concolor* (Sykes, 1832)	Dusky Crag Martin	I	R	_
	Pycnonotidae				
77	*Pycnonotus jocosus* (Linnaeus, 1758)	Red-whiskered Bulbul	O	R	_
78	*Pycnonotus cafer* (Linnaeus, 1766)	Red-vented Bulbul	O	R	_
79	*Pycnonotus luteolus* (Lesson, 1841)	White-browed Bulbul	O	R	×
	Sylviidae				
80	*Chrysomma sinense* (J.F. Gmelin, 1789)	Yellow-eyed Babbler	O	R	×
	Zosteropidae				
81	*Zosterops palpebrosus* (Temminck,1824)	Oriental White-eye	O	R	_
	Leiothrichidae				
82	*Argya malcolmi* (Sykes, 1832)	Large Grey Babbler	O	R	_
	Sturnidae				
83	*Pastor roseus* (Linnaeus, 1758)	Rosy Starling	O	WM	×
84	*Sturnia pagodarum* (J.F. Gmelin, 1789)	Brahminy Starling	O	R	_
85	*Acridotheres tristis* (Linnaeus, 1766)	Common Myna	O	R	_

	Order/Family/Scientific name	Common name	Food habit/ Guild	Residential status	Present status
	Muscicapidae				
86	*Saxicoloides fulicatus* (Linnaeus, 1766)	Indian Robin	C	R	_
87	*Copsychus saularis* (Linnaeus, 1758)	Oriental Magpie Robin	I	R	_
88	*Cyornis tickelliae* (Blyth, 1843)	Tickell's Blue Flycatcher	I	R	_
89	*Phoenicurus ochruros* (S.G. Gmelin, 1774)	Black Redstart	C	WM	×
90	*Monticola solitarius* (Linnaeus, 1758)	Blue Rock Thrush	I	WM	×

I—Insectivore | G—Granivore | F—Frugivore | C—Carnivore | O—Omnivore | R—Resident | WM—Winter migratory | SM—Summer migratory | _—Recorded at the study site in 2018 | ×—Not recorded at the study site in 2018.
Note: Birds those feed exclusively on insects are classified into insectivore; birds those feed on insects, invertebrates and vertebrates are classified as carnivore.

Table 2. List of bird species newly recorded in the campus of Savitribai Phule Pune University and Khadki pond in 2018.

	Order/Family/Scientific name	Common name	Food habit/ Guild	Residential status	Present status
	Anseriformes: Anatidae				
1	*Anas poecilorhyncha* (J.R.Forster, 1781)	Indian Spot-billed Duck	H	R	_
	Galliformes: Phasianidae				
2	*Pavo cristatus* (Linnaeus, 1758)	Indian Peafowl	O	R	_
3	*Francolinus pondicerianus* (J.F. Gmelin, 1789)	Grey Francolin	O	R	_
	Pelecaniformes :Ardeidae				
4	*Ardea intermedia* (Wagler, 1829)	Intermediate Egret	C	R	_
5	*Egretta garzetta* (Linnaeus, 1766)	Little Egret	C	R	_
	Phalacrocoracidae				
6	*Microcarbo niger* (Vieillot, 1817)	Little Cormorant	P	R	_
	Charadriiformes: Scolopacidae				
7	*Tringa ochropus* (Linnaeus, 1758)	Green Sandpiper	C	WM	_
	Coraciiformes: Alcedinidae				
8	*Alcedo atthis* (Linnaeus, 1758)	Common Kingfisher	C	R	_
	Psittaciformes: Psittaculidae				
9	*Psittacula eupatria* (Linnaeus, 1766)	Alexandrine Parakeet	G, F	R	_
	Passeriformes: Rhipiduridae				
10	*Rhipidura aureola* (Lesson, 1831)	White-browed Fantail	I	R	_
	Monarchidae				
11	*Terpsiphone paradisi* (Linnaeus, 1758)	Indian Paradise-flycatcher	I	R	_
	Dicaeidae				
12	*Dicaeum erythrorhynchos* (Latham, 1790)	Pale-billed Flowerpecker	O	R	_
	Acrocephalidae				
13	*Acrocephalus dumetorum* (Blyth, 1849)	Blyth's Reed Warbler	O	WM	_
	Sturnidae				
14	*Acridotheres fuscus* (Wagler, 1827)	Jungle Myna	O	R	_
	Muscicapidae				
15	*Ficedula parva* (Bechstein, 1792)	Red-breasted Flycatcher	I	WM	_
16	*Saxicola caprata* (Linnaeus, 1766)	Pied Bushchat	I	R	_

I—Insectivore | G—Granivore | F—Frugivore | C—Carnivore | P—Piscivore | H—Herbivore | O—Omnivore | R—Resident | WM—Winter migratory.
Note: Birds that feed exclusively on insects are classified as insectivore; birds those feed on insects, invertebrates and vertebrates are classified as carnivore.

Image 3. Khadki Pond in December 2018.

gardens containing exotic grass and ornamental plant species. Major construction work took place over open spaces and grassy patches, and many old trees of *Ficus benghalensis* were cut down for constructing sports complexes. Concrete fencing and gardening along the roads have cleared native vegetation. These activities have contributed to a decrease in the richness of avifauna which depend on low scrub jungle, grasslands, and fallow lands.

World biodiversity is facing the threat of exotic plants due to increased trade and transport. Exotic plantations in natural habitats gradually displace birds typical to that habitat (Daniels et al. 1990) and support generalist bird species (Zurita et al. 2006). Significantly less arthropod mass is supported by exotic plants compared to a native plantation, and fewer birds prefer exotic plants (Herrera & Dudley 2003; Flanders et al. 2006; Hickman et al. 2006; Ortega et al. 2006). Natural vegetation in the campus is replaced by exotic plants; *Dalbergia melanoxylon* and *Gliricidia sepium* are dominant exotic plants in the campus. *Gliricidia sepium* is known herbicidal plant; it has nematicidal and insecticidal activity (Nazali et al. 2008). *Gliricidia sepium* could have reduced herb, shrub and grass cover, reduced invertebrate and vertebrate fauna depending on it, and ultimately it might have affected the bird species diversity. Khadki pond was a perennial pond (Goel 1976), now transformed into seasonal pond (Image 3) that has been overtaken by natural vegetation due to blockage of water channels. The pond is surrounded by a plantation of exotic plant species *Acacia mearnsii* (Australian acacia) and *Euclyptus globulus,* and because of these changes the number of aquatic bird species has declined in Khadki pond. In addition to the above mentioned disturbances, there has also been a tremendous increase in human settlements in the area surrounding the campus, which might act as a barrier between campus and surrounding hilly regions. Pune is the eighth largest and fastest growing metropolis in India. From 1967 to 1998, area under human settlements in Pune city increased by 2.4 times, while area under agriculture and grassland-scrub decreased by 31% and 39% respectively (Nalavade 2000–2001). In 2000, 40% (60% in 1950) of total Pune urban area was under agriculture, 40% (15% in 1950) under human habitation, 6% (7% in 1950) under forest, 3% (0% in 1950) under plantations (Dixit et al. 2000–2001). We also noticed that richness of both resident and migratory birds declined and it is because of the unsuitability of the habitat. Urbanization was the main cause for encroachment of all the natural habitats in Pune urban area and thus bird diversity has declined in all habitat types (Ingalhalikar et al. 2000–2001).

It is, thus, concluded that increased anthropogenic activities in the university campus and surroundings has led to a decrease in bird diversity. Replacing exotic plantation with indigenous plants and restricting anthropogenic activities could prevent further biodiversity loss in the campus. Further studies are needed to check the impact of *Gliricidia sepium* the most planted exotic plant species on the plateaus in the Pune urban area through urban joint forest management programme, on the native biodiversity on a larger scale.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 17999–18003
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6193.13.3.17999-18003
#6193 | Received 20 May 2020 | Final received 19 January 2021 | Finally accepted 07 March 2021
PLATINUM OPEN ACCESS

SHORT COMMUNICATION

Sandracottus vijayakumari (Coleoptera: Dytiscidae), a new aquatic beetle species from landslide hit area of Nelliyampathy Forest Range, Western Ghats, Kerala, India

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Abstract: The present study deals with the description of a new species *Sandracottus vijayakumari* from Nelliyampathy forest range, southern Western Ghats, Kerala, India with a comparative key of closely related species *S. dejeani* Aube, 1838. Only one species is known from the genus *Sandracottus* Sharp, 1882, from southern Western Ghats, Kerala. The Nelliyampathy forest areas are hilly and the altitude of the hills range 40–1,530 m. The region experiences several types of landslides especially during the monsoon (August to September 2018). The new species was discovered in one of the worst landslide hits area in Nelliyampathy forest, Kundrachola region. The new aquatic beetle species is moderately large in size and often very attractively marked dorsally with complex maculations. Additionally, the new species shows a strong synapomorphy along with Eretini, Hydaticini, and Aubehydrini tribes.

Keywords: Aquatic beetle, insect, Kundrachola, monsoon, southern Western Ghats.

The adephagan beetles are one of the most successful groups of insects, distinguished by their adaptive nature in diverse ecological and geographical ranges. Most aquatic beetles are considered ecological indicators and their diversity is directly correlated with the ecosystem (Hutchison 1959; Boughey 1968; Benetti et al. 2003; Benetti & Regil-Cueto 2004). The factors like wave action, wind velocity, and scarcity of emergent vegetation presumably discourage the colonization of aquatic beetles. The abundance of macrophytic vegetation provides necessary shelter, shade, and substrate for colonization of aquatic beetles in the rainy and post-rainy season (Fernando 1968). Seasonal variation of the insect community in the rain pools, biotic patterns, some physical and meteorological variables were analyzed and found that the maximum taxonomic richness was observed at the end of summer (Fischer et al. 2000).

In India, the aquatic beetle diversity is poorly known. Dytiscidae is a large family of aquatic beetles, harbouring over ~300 species in India and adjacent countries. The Indian dytiscids have been chiefly studied by Vazirani (1968–1977) where he dealt with 233 species from

ZooBank: urn:lsid:zoobank.org:pub:A04B95E7-E565-413D-B6AD-32A0DA508D9E

Editor: Asheesh Shivam Mishra, Nehru Gram Bharati, Prayagraj, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Anand, P.P., P.P. Ashiq, M. Smitha, M. Adhithya, T. Tibin & V. Suresh (2021). *Sandracottus vijayakumari* (Coleoptera: Dytiscidae), a new aquatic beetle species from landslide hit area of Nelliyampathy Forest Range, Western Ghats, Kerala, India. *Journal of Threatened Taxa* 13(3): 17999–18003. https://doi.org/10.11609/jott.6193.13.3.17999-18003

Funding: KERALA STATE BIODIVERSITY BOARD order No. 48/3371/2018/KSBB dated 19.12.2018.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors gratefully acknowledge the financial assistance of Kerala State Biodiversity Board (KSBB), Government of Kerala, India. The first author is grateful to Dr. Y. Shibu Vardhanan, associate professor, Department of Zoology, University of Calicut for providing department laboratory facilities (UGC-SAP) and photographic documentation.

Image 1. Nelliyampathy forest with holotype collection locality (red colour).

India, out of which 69 species are from southern India. Till date, the majority of southern Indian species have been recorded from Tamil Nadu including Nilgiri Hills (Mukherjee & Sengupta 1986). During the biodiversity documentation of the flood and landslide hit area of Nelliyampathy, the authors came across a new species of *Sandracottus* Sharp, 1882 to science which has been described here and its comparison with the closely related species *S. dejeani* Aube, 1838 is also provided along with identification keys.

Materials and Methods

Study area

The present study was conducted at various locations in the Nelliyampathy Hills, Western Ghats, Kerala, India in view of the floods and landslides that occurred as a result of the heavy downpour of August and September 2018 that resulted in heavy damage in Kerala, India.

Specimen collection

Specimens were collected from a small rock of pool habitat in the landslide hit area of Nelliyampathy forest range in Kundrachola region (515m, 10^{0}30’58’’N & 76^{0}37’51”E) of southern Western Ghats (Image 1, 2). An aquarium hand net (Miller & Bergsten 2016) was used to collect the samples during the cool dry season from January to March 2019; a total of seven specimens were collected from the field and preserved in 80% ethanol prior to mounting. The holotype and paratype is deposited in the Department of Zoology, University of Calicut (DZUC). Specimens were imaged with a Canon EOS 5D Mark IV camera with MP-E 65mm lens, f/2.8 1-5X. Morphological terminology is according to Miller & Bergsten (2016). Identification was done based on available literature and taxonomic keys (Regimbart 1899; Mukherjee & Sengupta 1986; Nilsson 2001; Miller & Bergsten 2014; Miller & Bergsten 2016).

Results

Systematic position

Family: Dytiscidae Leach, 1815
Subfamily: Dytiscinae Leach, 1815
Tribe: Aciliini Thomson, 1867
Genus: *Sandracottus* Sharp, 1882

Sandracottus vijayakumari sp. nov. (Image 3A–D)

urn:lsid:zoobank.org:act:5885D8BA-1045-4CEE-A42C-4D2496FCB5F9

Material examined: Holotype: DZUC/Dyt01/2020, 17.iii.2019, male, India: Kerala, Palakkad, southern Western Ghats, Nelliyampathy forest range- Kundrachola (10^{0}30’58’’N & 76^{0}37’51”E), coll. P.P. Anand.

Paratype: DZUC/Dyt02/2020, 1 male with same data as holotype.

Description: Holotype male: length= 16.0mm;

Image 2. Kundrachola region (Nelliyampathy forest range) landslide hit area (Habitat of *Sandracottus vijayakumari* sp. nov.). © P.P. Anand

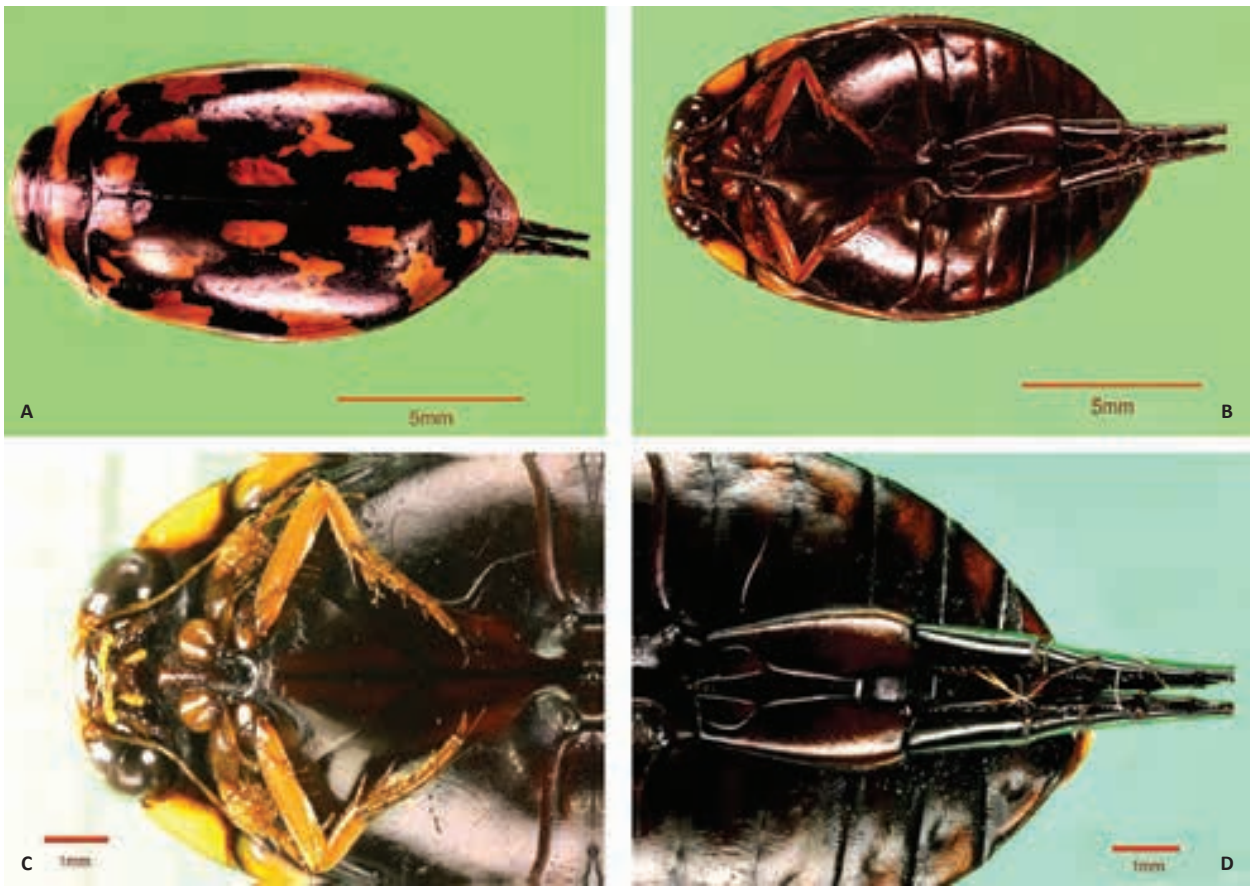

Image 3. *Sandracottus vijayakumari* sp. nov. Holotype (male): A—dorsal view with distinct color patches | B—ventral view | C—head, ventral view with mouth parts with pro and mesolegs, protarsus expanded to adhesive pads | D—posterior side of abdomen. © Y. Shibu Vardhanan

width= 13.5mm. Body oval, elongated; surface shiny; latteral reddish-orange colored line become reduced by reaching the posterior end of the pygidium; not dorso-ventrally flattened. Deep punctures on the pronotum and elytra. Dorsal surface black with distinct reddish-orange patches and with four dark-orange-colored spots parallelly arranged in elytra. All patches on each elytron are mirror images of other elytron. The first three dark orange patches are interconnected and other two are distinct (Image 3A). Head capsule is dark orange black colored with clypeus and frons testaceous. Elytron contains numerous punctures, a coarse puncture line pass through the middle of elytra in antero-posterior direction. Ventral surface is predominantly black with

Key to genera (Miller & Bergsten 2016)

1 Mesofemur with longer ventral setae, at least some as long as ½ x width of mesofemur; body length greater (11.0–15.5 mm) ..... *Sandracottus* Sharp, 1882

1' Mesofemur with shorter ventral setae, less than ¼ x width of mesofemur; body length shorter (7.5–11.0 mm) ..... *Rhantaticus* Sharp, 1880

Key to species (modified from Miller & Bergsten 2016)

The new species *Sandracottus vijayakumari* sp. nov. is morphologically similar to *S. dejeani* Aube, 1838.

1 Head being reddish-yellow; posterior border of vertex black; head without fine microreticulation and setiferous punctures; pronotum with a few black and comparative coarse puncture; elongated protarsus with adhesive disc without distinct spur; meso and meta tarsomeres have series of golden setae along the apical margins; dorsal elytra darkish orange patches largely separated and connect by narrow bridges ..... *Sandracottus dejeani* Aube, 1838.

1' Head dark black with yellowish patch; Head with fine microreticulation and numerous small setiferous punctures; pronotum and elytra with well distinct punctures and presence of longitudinal punctures (Image 3a); protarsus expanded and rounded suckers with distinct spur, adhesive disc (Image 3c); Meso and meta tarsomeres with a series of black setae along the apical margins (Image 3c,d). The dorsal elytral darkish-orange patches are distinctly separated from each other (Image 3a) ..... ***Sandracottus vijayakumari* sp. nov.**

distinct organization of appendages (Image 3B).

Structure: Large black color compound eye and cranium, not emarginated; scutellum clearly visible with elytra closed. Filiform antennae and antennomeres 11 (Image 3C); posterior margin of pronotum elevated with dark orange colored mark. Pronotum without lateral bead. In ventral part, distinct prosternal process and discrimen; elytral epipleuron ends in 4th ventrites. Well distinct metatibial spur with numerous long setae present. Ventral surface of pro- and meso-tarsomeres broadly expanded into rounded palette with ventral adhesive setae; male median lobe symmetrical, protected by numerous spurs. Protarsi distinctly pentamerous, tarsomere IV is smaller than the others (Image 3C). Apices of both metatibial spurs bifid; series of bifid setae on posterior surface of metatibia oblique. Margins of sternites 6 & 7 are somewhat bordered. Mesotibiae with four natatorial setae (Image 3C); metatibiae is found without natatorial setae (Image 3D).

Female: Unknown

Diagnosis: This species shows close relation with *Sandracottus dejeani* Aube, 1838 except in the case of presence of head with fine microreticulation and numerous small setiferous punctures.

Distribution: Known only from the type locality.

Etymology: The species is named in honor of Mr. Vijayakumar PK (Aka. Vijayakumar Blathur), Popular science writer in Malayalam for his ardent passion towards insects.

Ecology: Most of the seven specimens of *Sandracottus vijayakumari* sp. nov. were collected in a partly shaded, shallow, ditch-like forest pool which was rich in decaying leaves and twigs; lentic habitat.

Discussion

Dytiscinae contains five tribes, and 12 genera in total. These are among the largest of all diving beetles in the world. They are characteristic of pond and lakes, but they can be found in different ecosystems, with extensive marginal vegetation. Many of the largest have been involved in predation on vertebrates, some of them may rarely act as competition in fish farming (Wilson 1923; Bishat & Das 1979, 1985; Balke & Hendrich 1996; Adeyemo et al. 1997; Megna et al. 2019). In each biogeographic region, there are groups of Dytiscinae with main groups that are endemic to certain areas. They are well distributed in temperate and high altitude to tropical low land habitats (Miller & Bergsten 2014).

Until now, one species of *Sandracottus* was known, i.e., *S. dejeani* Aube, 1838 from Silent Valley National Park, southern Western Ghats, Kerala, in 1979 (Mukherjee & Sengupta 1986). *Sandracottus vijayakumari* sp. nov. shows a high similarity with the other tribes, however, analyzing the morphological taxonomic characters of this species shows close affinity to the tribe Aciliini. The strong resemblance between the two species (*S. vijayakumari* and *S. dejeani*) can be explained by the multiple convergence arising from a similar shift in

habitat. Throughout most biogeographical regions, Aciliines are found worldwide with distinct fauna and sometimes uncommon genera, with the exception of Australia, where Aciliines comprises rare species of *Sandracottus* and the extremely common *Rhantaticus congestus* (Klug, 1833) (Balke & Hendrich 1996).

Historically, Dytiscinae has been placed under Cybistrinae, which share a number of synapomorphies in both adult and larvae (Alarie et al. 2011; Miller & Bergsten 2014). The tribe Aciliini may act as connecting link between other diving beetles. The new species *S. vijayakumari*, may play a vital role in the evolutionary lineage of Dytiscinae. Ribera et al. (2002 & 2008) suggested that either *Eretes*or *Nottaticus*is nested within Aciliini, but the current evidence shows that *Eretini* is sister to Aciliini (Bukontaite et al. 2014) and Aubehydrini (*Notaticus*) is sister to that clade (Miller & Bergsten 2014). *Sandracottus* showed synapomorphy together with several other taxa such as Eretini, Hydaticini, and Aubehydrini, especially in the case of both metatibial spurs are apically bifid. Also, the line of bifid setae on the posterior surface of the metatibia is distinctly oblique with resected to the long axis of the tibia. More molecular and evolutionary studies are needed to assess the evolutionary origin and diversification of these taxa, and *S. vijayakumari* will help to the understand the convergent or divergent evolutionary pattern of *Sandracottus* genus. In past few years nobody studied the genus, and this genus is currently under revision (Miller & Bergsten 2014).

Conclusion

Sandracottus vijayakumari sp. nov. shows close morphological similarity with *S. dejeani*; however the latter is from Silent Valley, which is north of the Palghat gap of the Western Ghats, where as the new species is from south of the Palghat gap.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18004–18010
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6353.13.3.18004-18010
#6353 | Received 02 July 2020 | Final received 12 March 2021 | Finally accepted 15 March 2021
PLATINUM OPEN ACCESS
SHORT COMMUNICATION

The genus *Basiria* Siddiqi, 1959 (Nematoda: Tylenchidae) from Dezful region, Iran

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Abstract: A survey was conducted during 2018 and 2019 in order to identify plant-parasitic nematodes of the genus *Basiria* in Dezful region of Khuzestan province, southwestern Iran. Nematodes were extracted from the soil and root samples by using tray method, transferred to glycerin and mounted on permanent slides. Nematodes were identified based on morphological and morphometric characters. As a result, eight species including *B. aberrans*, *B. duplexa*, *B. gracilis*, *B. jirians*, *B. tumida*, *B. graminophila*, *B. ritteri*, and *B. similis* were identified; three species namely *B. jirians*, *B. ritteri*, and *B. similis* are here described and illustrated for the first time from Iran. *B. jirians* is characterized by body length 445–535 µm, stylet 9.0–9.2 µm, cephalic region without annuli, DGO 2.0–2.5 µm, median bulb at anterior end of pharynx, basal bulb pyriform, spermatheca non offset and tail elongate conoid with pointed to filiform terminus. *B. ritteri* can be characterized by body length 685–747 µm, stylet 10.5–11.5 µm, median bulb located at anterior half of pharynx, basal bulb cylindroid, spermatheca non offset and tail annulated and notched at tip. *B. similis* is characterized by body length 644–736 µm, stylet 10.3–11 µm, DGO 8.9–10.5 µm, basal bulb cylindroid and tail clavate.

Keywords: First report, Boleodorinae, natural habitats, nematode, southwestern Iran.

Members of the family Tylenchidae Örley 1880 are important soil fauna which may constitute up to 30% of the nematodes in any given soil sample (Qing et al. 2018). The genus *Basiria* Siddiqi 1959 belongs to the subfamily Boleodorinae Khan 1964 and currently contains 42 valid species (Geraert 2008), with *B. graminophila* Siddiqi 1959 as type species. During recent years, *B. birjandiensis* Alvani Mahdikhani-Moghadam Rouhani Mohammadi & Karssen, 2016 and *B. khouzestanensis* Eisvand Farrokhi & Azimi, 2019 were described from Iran. Hitherto, 10 species of the genus *Basiria* have been reported from Iran (Karegar 2018). The present study has characterized eight known species of the genus, including three new records from Iran, based on morphological and morphometric characters.

Materials and Methods

Soil samples were collected from the natural habitats in different localities of Dezful region, Khuzestan province, southwestern Iran. Nematodes were extracted by the tray method (Whitehead & Hemming 1965), killed and fixed by hot FPG (4:1:1, formaldehyde: propionic acid: glycerol), and processed to anhydrous glycerol (De Grisse 1969). Nematodes were mounted in glycerol on permanent slides using paraffin wax and studied using a light microscope, equipped with a dino-eye microscope eye-piece camera in conjunction with its Dino Capture version 2.0 software. Specimens were identified at species level using available identification keys (Karegar & Geraert 1998; Geraert 2008).

Editor: Anonymity requested. **Date of publication:** 26 March 2021 (online & print)

Citation: Hosseinvand, M., A. Eskandari & R. Ghaderi (2021). The genus *Basiria* Siddiqi, 1959 (Nematoda: Tylenchidae) from Dezful region, Iran. *Journal of Threatened Taxa* 13(3): 18004–18010. https://doi.org/10.11609/jott.6353.13.3.18004-18010

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors thank Dr. Akbar Karegar for kind help in identification of *B. ritteri*.

Results and Discussion

In this study we identified eight species of the genus including *B. aberrans* (Thorne, 1949) Siddiqi 1963; *B. duplexa* (Hagemeyer & Allen, 1952) Geraert 1968; *B. gracilis* (Thorne, 1949) Siddiqi 1963; *B. graminophila* Siddiqi, 1959; *B. jirians* Renubala & Dhanachand, 1992; *B. ritteri* (Baqri & Jairajpuri, 1969) Bernard 1980; *B. similis* (Thorne & Malek, 1968) Bernard 1980, and *B. tumida* (Colbran, 1960) Geraert 1968. Amongst them, three species, *B. jirians*, *B. similis*, and *B. ritteri*, are described and illustrated for the first time from Iran.

Basiria jirians Renubala & Dhanachand, 1992

(Table 1; Figure 1; Image 1)

Description

Female: Body straight to slightly ventrally arcuate following heat fixation. Cuticle annuli 1.0–1.2 µm wide at mid-body. Lateral field with four incisures, 3.4–4.2 µm wide, occupied 28–31 % of body diameter, without areolation. Lip region smooth, continuous with body, at front slightly flatted, 5.2–5.5 µm wide and 2.7–3.1 µm high. Amphidial aperture oblique, slit-like. Stylet with small basal knobs, 1.8–2.0 µm wide. Dorsal pharyngeal gland orifice (DGO) 2.0–2.5 µm posterior to stylet knobs. Median bulb oval, 7.0–7.5 µm wide and 14.0-14.5 µm long, with weakly developed valve, located at anterior half of pharynx. Isthmus slender. Excretory pore at 72–73 µm from anterior end. Nerve ring located at 60–65 µm from anterior end. Hemizonid at level of excretory pore, 71–72 µm from anterior end. Basal bulb pyriform, 6.2–8.9 µm wide and 14.5–18.5 µm long. Cardia indistinct. Reproductive system monodelphic-prodelphic, composed of an outstretched ovary with oocytes arranged in a single row. Spermatheca non-offset, slightly elongated, with rounded sperm, 15–22 µm long, 8.0–9.0 µm wide. Vulva a transvers slit lacking flaps or epiptygma. Vagina 4.0–4.5 µm long. Tail elongate-conoid, about equal to the vulva-anus distance, at tip pointed to filiform.

Male: General characters similar to the female. Spicule tylenchoid, small and slightly curved. Gubernaculum simple, rod-shape. Bursa ad-cloacal, simple. Tail similar to that of female.

Discussion

B. jirians is close to *B. dolichura* Loof, 1971, but it differs by smaller body length (490–530 µm vs. 820–930 µm), stylet length (8.0–9.0 µm vs. 9.0–11.0 µm), spermatheca (non-offset vs. offset), tail length (130–136 µm vs. 220–276 µm), and V ratio (61–62 % vs. 52–57 %).

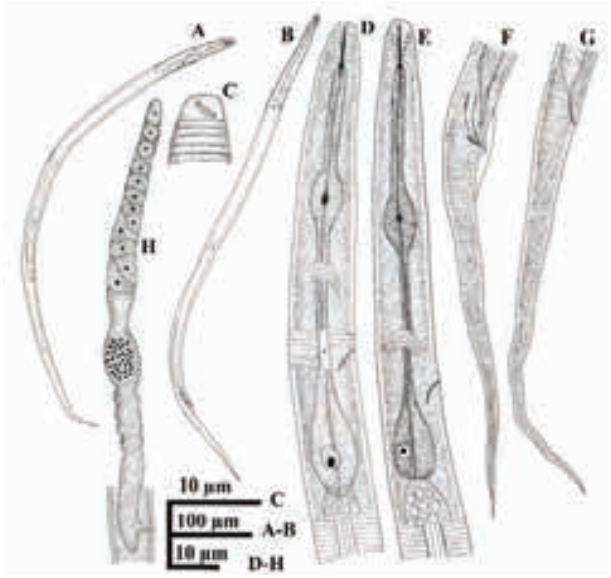

Figure 1. Iranian population of *Basiria jirians*. Female (A, C, E, G & H) and Male (B, D, F): A, B—entire body | C—amphidial aperture | D & E—anterior end | F, G—tail | H—reproductive system.

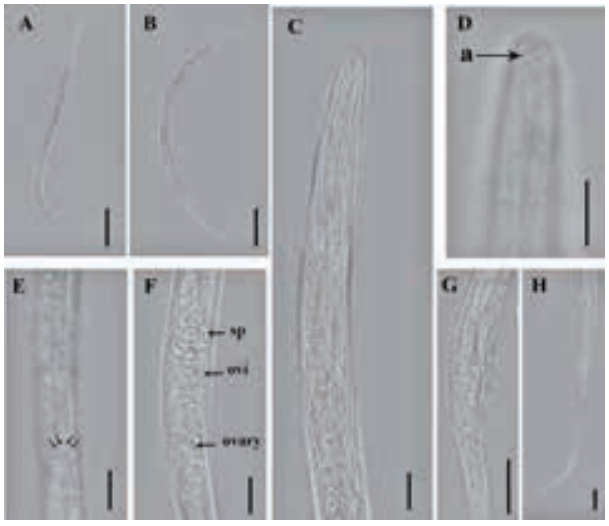

Image 1. Iranian population of *Basiria jirians*. Female (B, C, D–F & H) and Male (A & G): A, B—entire body | C—anterior end | D—amphidial aperture | E—lateral field | F—spermatheca and reproductive system | G, H—tail | A, B—100µm | C–H—10µm.

It differs from *B. birjandiensis*, by smaller stylet length (8.0–9.0 µm vs. 11–12 µm), DGO (2.0–2.5 µm vs. 6.0–9.0 µm), non-offset spermatheca (vs. offset), from *B. khouzestanensis* by smaller stylet (8.0–9.0 µm vs. 9.3–12.5 µm), DGO (2.0–2.5 µm vs. 4.0–6.0 µm) and position of median bulb (40–42 vs. 48–56.2), and from *B. elegans* (Khan & Khan 1975) Bajaj & Bhatti 1979 by smaller body (490–530 µm vs. 750–900 µm), cephalic region (smooth *vs.* annulated), stylet length (8.0–9.0 µm vs. 11–13 µm),

Table 1. Morphometric characters of *Basiria jirians and B. similis* population from Dezful region (measurements in µm) and in the form: mean ± s.d. (range).

	B. similis		*B. jirians*		
	Present study	**Geraert 2008**	**Present study**		**Renubala & Dhanachand 1992**
Character	Female	Female	Female	Male	Female
n	3	?	3	1	4
L (µm)	700 ± 49.3 (644–736)	680–700	490 ± 45 (445–535)	485	490–530
a	37.2 ± 2.4 (34.4–39)	42	37.6 ± 0.5 (37–38.2)	41.1	33–39
b	5.5 ± 0.2 (5.3–5.7)	-	5.1	16.1	6.1–7.3
c	7.5 ± 0.1 (7.5–7.6)	8.2	5.2 ± 0.2 (5.0–5.4)	5.3	3.7–3.9
c'	8.6 ± 0.5 (8.0–9.0)	-	10.8 ± 0.2 (10.6–11.1)	8.8	10–17
V	73.2	71.5–73	64.7 ± 1.3 (63.1–65.6)	-	61–62
V'	84.3 ± 0.1 (84.2–84.4)	82–83	80 ± 1.8 (78–81.7)	-	83
Stylet (µm)	10.6 ± 0.3 (10.3–11)	11–13	9.1 ± 0.1 (9.0–9.2)	9.3	8.0–9.0
Conus (µm)	3.7 ± 0.1 (3.7–3.8)	-	3.0 ± 0.2 (2.9–3.2)	3.1	-
O	92 ± 4.9 (86.4–95.4)	-	25.7 ± 3.0 (22.2–27.7)	37.6	-
Pharynx (µm)	125 ± 3.7 (121–128)	122–125	94.6 ± 8.5 (86–103)	102	76–80
Median bulb (µm)	46 ± 1.1 (45–47)	-	38.5 ± 1.5 (37–40)	46	40–43
MB	36.9 ± 0.2 (36.7–37.1)	40	40.7 ± 2.1 (38.8–43)	45	39.6–42.0
Deirids	95 ± 1.5 (94–97)	-	74 ± 1.0 (73–75)	81	-
Head-vulva (µm)	513 ± 35.9 (472–539)	-	317 ± 30.7 (291–351)		-
Head-anus (µm)	608 ± 42 (560–638)	-	396 ± 40.5 (356–437)	393	-
Vulva-anus (V-A)(µm)	95 ± 6.0 (88–99)	-	79 ± 12.4 (65–87)	-	61.7–70.4
Tail/V-A	0.9	0.8–0.9	1.1 ± 0.1 (1.0–1.3)	-	2.0
Body width (µm)	18.8 ± 0.1 (18.7–19)	16.5–18	13 ± 1 (12–14)	11.8	-
Vulval body width (VBW) (µm)	15.8 ± 0.2 (15.5–16)	-	12.2 ± 0.2 (12.0–12.5)		-
Anal body width (µm)	10.7 ± 0.1 (10.5–10.8)	-	8.6 ± 0.6 (8.0–9.2)	10.4	-
Annulus width (µm)	1.2 ± 0.1 (1.1–1.4)	-	1.1 ± 0.1 (1.0–1.2)	1.0	-
PUS	10.8 ± 0.3 (10.6–11.2)	12	10 ± 0.5 (9.5–10.5)	-	-
PUS/VBW (%)	68 ± 3.3 (66–72)	80	82 ± 2.4 (79–84)	-	-
Tail length	92 ± 7.3 (84–98)	85–87	93 ± 4.5 (89–98)	92	128–136
Spicules	-	-	-	13.8	14.5–15
Gubernaculum	-	-	-	5.5	3.0
Bursa	-	-	-	25.0	21

tail length (130–136 µm vs. 192–218 µm) and spicule length (14–15 µm vs. 25–26 µm).

Our population is very close to *B. jirians*, but differs from the type population in tail length (89–98 µm vs. 130–136 µm), pharynx length (86–103 µm vs. 76–80 µm) and position of vulva (63.2–65.6 % vs. 61–62 %). These differentiations, however, maybe related to habitat and associated host. In this study, it was found from the rhizosphere of *Nerium oleander* in Dezful region.

***Basiria similis* (Thorne & Malek, 1968) Bernard, 1980**

(Table 1; Figure 2; Image 2)

Description

Female: Body straight to slightly ventrally curved. Body annuli delicate, 1.1–1.4 µm wide at mid-body. Lateral field with four incisures, 5.4–6.0 µm occupying 29–32 % of body wide. Cephalic region with four annuli at body contour, 6.3–6.5 µm width and 3.1–3.4 µm high. Cephalic framework weekly sclerotized. Amphidial aperture obligate, slit-like. Stylet delicate with distinct

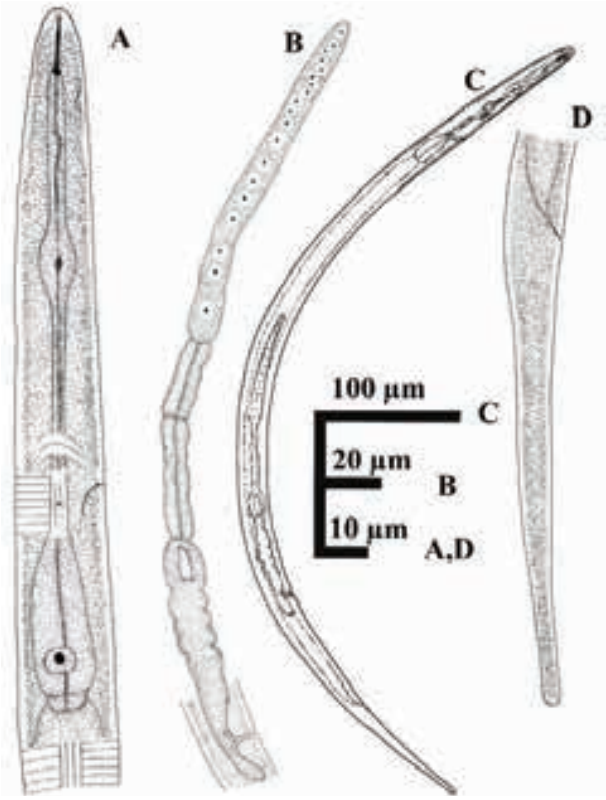

Figure 2. Iranian population of *Basiria similis*. Female (A–D): A—anterior end | B—reproductive system | C—entire body | D—tail.

Image 2. Iranian population of *Basiria similis*. Female (A–F): A—entire body | B—reproductive system | C, D—stylet and DGO | E—anterior end | F—tail | A—100µm | B–F—10µm.

knobs, 1.5–2.1 µm wide, conus 33-37% of total stylet length. Dorsal pharyngeal gland orifice (DGO) 8.9–10.5 µm posterior to stylet knobs. Median bulb oval, 7.0–8.5 µm, occupied 49–55 % of body wide, with distinct valve, located at first half of pharynx. Isthmus slender. Excretory pore at 85–94 µm from anterior end. Nerve ring located at 77–82 µm from anterior end. Hemizonid 1–3 annuli anterior to excretory pore, 84–93 µm from anterior end. Basal bulb cylindroid, 10.0-12.0 µm wide and 27–29 µm long. Deirids at level of excretory pore. Cardia large and rounded. Reproductive system monodelphic-prodelphic, ovary long. Spermatheca non-offset, elongated and rectangular, without sperm. Vulva a transvers slit lacking flaps or epiptygma. Vagina 6.0–6.5 µm long that occupied 26–30 % of corresponding body wide in length. Tail elongate-clavate.

Male: Not found.

Discussion

B. similis is very close to *B. diversicauda* Khan 1993, *B. tumida*, and *B. ritteri*. It differs from *B. ritteri* by clavate tail (vs. notch at tip), annulation at posterior half of tail indistinct (vs. annuli at entire tail distinct) and DGO (10–11 µm vs. less than 4.0µm). It can be distinguished from *B. tumida* by DGO (10–11 µm *vs.* 1.5–4.5 µm), and from *B. diversicauda* by only tail shape (clavate vs. elongate-conoid to a rounded terminus). *B. diversicauda* probably is a synonym of *B. similis* (Karegar & Geraert 1997). This species has been described only from an apple orchard in South Dakota, USA (Thorne & Malek 1968). Morphological and morphometric characteristics of our population fit well with those of *B. similis*. In this study, it was recovered from the rhizosphere of wild grasses in Dezful region.

Basiria ritteri (Baqri & Jairajpuri, 1969) Bernard, 1980

(Table 2; Figure 3; Image 3)

Description

Female: Body straight to slightly ventrally curved. Body annuli delicate, 1.3–1.5 µm wide at mid-body. Lateral field with four incisures, 5.7–6.2 µm that occupied 25–27 % of body wide. Cephalic region with four to five annuli, not offset from body, 6.1–6.6 µm wide and 3.1–3.4 µm high. Cephalic framework weekly sclerotized. Amphidial aperture obligate, slit-like. Stylet delicate with distinct knobs, 1.9–2.3 µm wide, conus

Table 2. Morphometric characters of *Basiria ritteri* population from Dezful region (measurements in µm) and in the form: mean ± s.d. (range).

	Present study		Baqri & Jairajpuri 1969	Karegar & Geraert 1997
Character	**Female**	**Male**	**Female**	**Female**
n	4	4	7	14
L (µm)	713 ± 31.3 (685–747)	666 ± 60.5 (618–734)	480–680	625–775
a	32 ± 0.9 (31–33)	39± 2.6 (36–41)	-	-
b	5.5 ± 0.2 (5.3–5.7)	13.7 ± 0.5 (13.2–14.3)	-	-
c	7.3 ± 0.2 (7.2–7.6)	7.3 ± 0.2 (7.0–7.4)	-	-
c'	8.1 ± 0.2 (7.9–8.3)	7.0 ± 0.6 (6.3–7.6)	-	-
V	72.2 ± 1.6 (70.3–73.4)	-	71–77	71–76
V'	83.5 ± 1.7 (81.6–85.1)	-	81–85	82–85
Stylet (µm)	10.9 ± 0.5 (10.5–11.5)	10.9 ± 0.3 (10.6–11.2)	9.0–10	8.5–11.0
Conus (µm)	3.7 ± 0.2 (3.6–4.0)	3.8 ± 0.2 (3.6–4.1)	-	-
O	24.4 ± 1.4 (23.3–26)	22.5 ± 1.7 (20.5–23.6)	-	-
Pharynx (µm)	128 ± 1.0 (127–129)	123 ± 5.1 (117–127)	120	101–128
Median bulb (µm)	48.5 ± 0.5 (48–49)	47 ± 2.0 (45–49)	-	-
MB	37.7 ± 0.2 (37.5–37.9)	38.3 ± 0.3 (37.9–38.5)	36.5	34–39
Deirids	94.3 ± 0.5 (94–95)	94 ± 0.5 (94–95)	-	-
Head-vulva (µm)	516 ± 31.7 (482–545)	-	-	-
Head-anus (µm)	617 ± 29.9 (590–649)	575 ± 53.6 (535–636)	485–565	550–705
Vulva-anus (V-A) (µm)	101 ± 8.8 (91–108)	-	-	-
Tail/V-A	0.9 ± 0.1 (0.8–1.0)	-	0.5–1.0	0.6–1.0
Body width (µm)	22.6 ± 1.5 (21–24)	17.3 ± 2.0 (15–19)	15–17.5	-
Vulval body width (µm)	19.6 ± 0.5 (19–20)		-	-
Anal body width (µm)	11.8 ± 0.2 (11.6–12)	12.8 ± 0.7 (12–13.5)	-	-
Annulus width (µm)	1.3 ± 0.1 (1.3–1.5)	1.2 ± 0.1 (1.2–1.3)	-	-
PUS	10.4 ± 0.3 (10–10.7)	-	-	-
PUS/VBW (%)	53 ± 2.6 (50–55.2)	-	30–80	-
Tail length	97 ± 1.5 (95–98)	91 ± 7.5 (83–98)	49–68	59–95
Spicules	-	18.1 ± 1.0 (17–19)	16–17	15
Gubernaculum	-	5.2 ± 0.2 (5–5.5)	4.0–5.0	4.5
Bursa	-	25.3 ± 0.5 (25–26)	-	-

33–35 % of total stylet length. Dorsal pharyngeal gland orifice (DGO) 2.5–3.0 µm posterior to stylet knobs. Median bulb oval, 8.0–8.6 µm, occupied 50–57 % of body wide, with distinct valve, located at posterior half of pharynx. Isthmus slender. Excretory pore at 87–99 µm from anterior end. Nerve ring located at 85–90 µm from anterior end. Hemizonid 1–3 annuli anterior to excretory pore, 89–92 µm from anterior end. Basal bulb cylindroid, 12.0–13.0 µm wide and 27–30 µm long. Deirids at level of excretory pore. Cardia large and funnel-shape. Reproductive system monodelphic-prodelphic, ovary very long. Spermatheca non-offset, elongated and rectangular, with rounded sperm, 25–28 µm long and 10–12 µm in wide. Vulva a transvers slit lacking flaps or epiptygma. Vagina 5.8–6.2 µm long occupying 25–27 % of corresponding body wide. Tail elongate-conoid, with distinct annulation, tapering gradually, terminus with notched.

Male: General characters similar to female, cephalic region slightly smaller than female. Spicules arcuate and tylenchoid. Gubernaculum simple. Bursa ad-cloacal.

Discussion

This species was firstly described as *Basiroides ritteri* Baqri & Jairajpuri 1969 from India, then, Bernard (1980) transferred it to the genus *Basiria*. It is very similar to *B. guangdongensis* (Xie, Feng, Li & Yin, 1994) Siddiqi 2000 *B. similis*, and *B. tumida*. It can be differentiated from *B.*

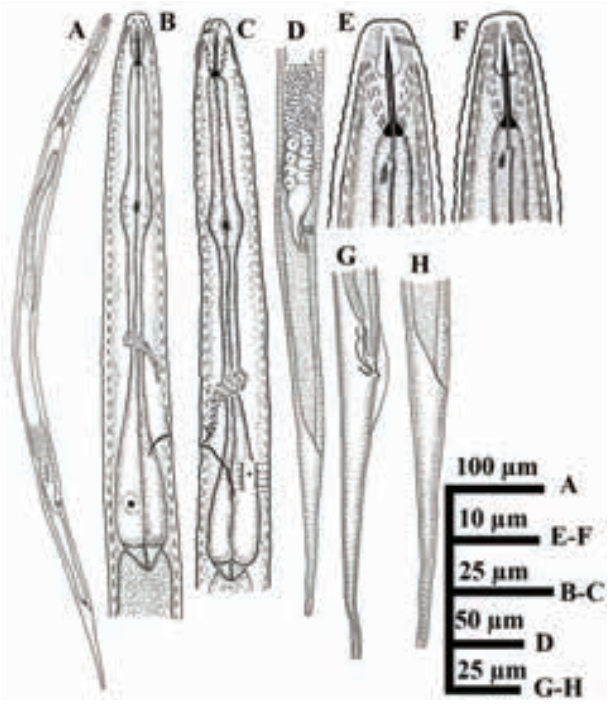

Figure 3. Iranian population of *Basiria ritteri*. Female (A, B, D, F & H) and Male (C, E, G): A—entire body | B, C—anterior end | D—posterior end | E, F—stylet and cephalic region | G, H—tail.

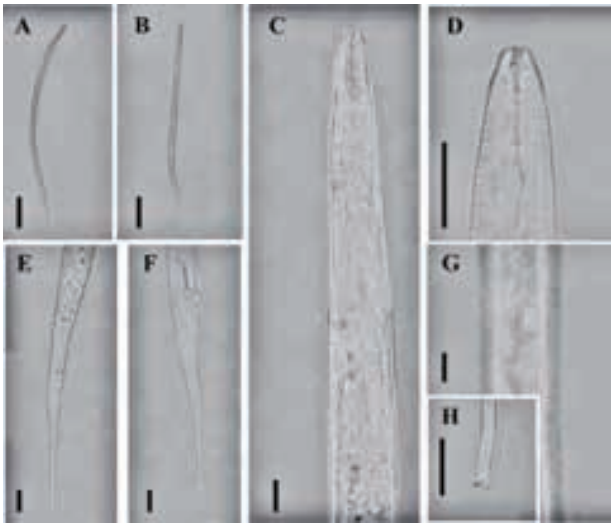

Image 3. Iranian population of *Basiria ritteri*. Female (B-E, G) and Male (A, F, H): A, B—entire body | C—anterior end | D—stylet and cephalic region | E, F—posterior end | G—lateral field | H—tail tip | A, B—100µm | C–H—10µm.

guangdongensis by stylet length (8.5–11.0 µm vs. 12.5–13 µm). It can be separated from *B. similis* by slightly shorter stylet (8.5–11.0 µm vs. 11–13 µm), DGO (2.0–3.5 µm vs. 10–11 µm), and tail tip (notched vs. not notched), and from *B. tumida* by tail tip (notched vs. not notched), entire tail annulated (vs. posterior part of tail without distinct annulation). Our population is very similar to the *B. ritteri* and all morphological and morphometrical characters are close to the type population. This species has been found only in Asia, Uttar Pradesh (as type locality), India (Baqri & Jairajpuri 1969); Pakistan (Maqbool et al. 1984 as *Basirioides sindhicus*); China and Vietnam (Karegar & Geraert 1997). In this study, it was recovered from the rhizosphere of *Polianthes tubeosa* in Dezful region.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18011–18014
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6167.13.3.18011-18014
#6167 | Received 15 May 2020 | Final received 21 June 2020 | Finally accepted 15 March 2021
PLATINUM OPEN ACCESS
SHORT COMMUNICATION

A new species of braconid wasp *Meteorus* Haliday (Hymenoptera: Braconidae: Meteorinae) from India

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Abstract: A new species of braconid wasp, *Meteorus rubrum* Ahmed & Shamim sp. nov. (Hymenoptera: Braconidae: Meteorinae), is described from India. The new species is closely related with *M. dichomeridis* (Wilkinson, 1930) and *M. kotanni* (Maeto, 1986).

Keywords: *Meteorus dichomeridis, M. kotanni,* Rajouri, wasp.

Haliday (1835) erected the genus *Meteorus* with its type species *Ichneumon pandulator* Latreille. The genus is distinguished by maxillary palp six segmented, forewing vein SR1 usually long and straight, first metasomal tergite slender and long. This genus is studied well by Muesebeck (1936), Nixon (1943), Huddleston (1980, 1983, 1986), and Maeto (1986, 1988a,b, 1989a,b, 1990). It includes 412 species from all over the world (Yu 2020), out of which 11 species have been described and reported from India so far, viz.: *Meteorus arcticida* (Viereck, 1912), *M. dichomeridis* (Wilkinson, 1930), *M. spilosomae* (Narendran & Rema, 1996), *M. etawahiana* (Shamim & Ahmad, 2008), *M. poonchiensis* (Shamim & Ahmad, 2008), *M. aurayyus* (Shamim, 2011), *M. hayati* (Shamim, 2011), *M. indicus* (Shamim, 2011), *M. narendrani* (Shamim, 2011), *M. sharifi* (Shamim, 2011), and *M. aligarhensis* (Shamim & Usmani, 2012). All of these species are koinobiont endoparasitoids, usually attack young exposed-feeding caterpillars, but some of the species parasitize grubs (Shaw & Huddleston 1991; Shaw 1997). *Meteorus* species are famous for their diverse silk-spinning, and cocoon-forming behaviours (Zitani et al. 1997). In this paper a new species *Meteorus rubrum* is illustrated and described from India.

Material and Methods

The specimens were collected by using sweep net. The slides and card mounts of specimens were examined through stereo zoom binocular microscopes (Nikon SMZ1500 and Nikon SMZ 25). The ocular micrometer was used for the measurement (linear side of 100 divisions) of body parts. The ocular micrometer was calibrated with the help of stage micrometer under 8x10x magnification. Photographs were taken at different magnifications (4–16x) by the camera attached to Stereozoom binocular microscope. The general terminologies and venation terminologies followed given by Achterberg (1993) and for the surface sculpture followed Eady (1968). The following acronyms are used to denote the various body

ZooBank: urn:lsid:zoobank.org:pub:7BBB9780-97A2-4304-A654-41BED566DDFB

Editor: Farmanur Rahman Khan, Qassim University, Buraidah, Kingdom of Saudi Arabia. **Date of publication:** 26 March 2021 (online & print)

Citation: Ahmed, Z., A.H. Mir & M. Shamim (2021). A new species of braconid wasp *Meteorus* Haliday (Hymenoptera: Braconidae: Meteorinae) from India. *Journal of Threatened Taxa* 13(3): 18011–18014. https://doi.org/10.11609/jott.6167.13.3.18011-18014

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We thanks Dr. Mohd Kamil Usmani Professor and Head, Section of Entomology, Department of Zoology, Aligarh Muslim University for providing laboratory facilities

parts: AOL= Anterior ocellar line; POL= posterior ocellar line; OOL= ocello ocular line; OOD= ocellus diameter; F: flagellomere; T= thoracic terga; 1-CU1= first cubitus, 2-CU1= second cubitus, 3-CU1= third cubitus. Acronym for type depository MDZUK= Museum Department of Zoology, University of Kashmir

Results and Discussion

Meteorus rubrum Ahmed & Shamim, sp. nov. (Image 1 A–K)

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Material examined

Holotype: ZoKU Art/06179, 25.vi.2019, Female, Palma, Rajouri, Jammu & Kashmir (UT), India, coll. Zaheer Ahmed, deposited in MDZUK.

Paratype: ZoKU Art/06179a, 1 Female, data same as holotype.

Female: Body length: 8.87mm; Forewing: 8.45mm.

Head: The width of head in dorsal view 1.6x of its length and 1.4x of height; occipital carina complete; length of eye in lateral view 1.4x of its width and 1.8x of temple; temple setose, OOL:POL:AOL:OOD= 7:10:5:9; vertex smooth and densly setose, width of vertex 2.5x of its length; frons smooth and shiny with median longitudional carina, width of frons 3.5x of its length; face rugose and densely setose; width of face 1.8x of its length; tentorial pits deep and broad; intertentorial line 4.3x of tentorio-ocular line; length of malar space 3.3x of basal width of mandible; clypeus convex and sparsely setose, length of clypeus 2.7x of its width; antennal segments 38; length of scape 1.2x of its width, pedicel as long as wide, length of F1- F4 :3.4x: F5-F9 3x: F5-F9 2.8x: F10 –F13 2.2x: F14 –F26 2x: F27- F28: 2.6x: F29: 2.3x: F30 -F34 :2x: F35: 1.6x: F36 3.5x of their widths respectively.

Mesosoma: Length of mesosoma 2.6x of its width and 2.8x of its height; dorsal surface of pronotum smooth, laterally rugulose punctate; notauli deep, anteriorly crenulate, posteriorly rugose; mesopleuron anteriorly rugose, medially with some crenulation and posteriorly longitudinally striate, metapleuron reticulate and sparsely setose; scutellar sulcus shallow without any carina; scutellum smooth, sides of scutellum rugose; metanotum anteriorly smooth, laterally crenulate; sternulus smooth and shallow; propodeum entirely reticulate rugose.

Legs: Hind coxa 1.4x as long as wide; length of hind femur, tibia, and basitarsus 5.7x, 12x, and 1.8x their widths respectively; length of hind tibial spurs 0.28x–0.35x of hind basitarsus.

Wings: Length of forewing 2.9x of its width, length of pterostigma 3.3x of its width, length of vein 1-R11.4x length of pterostigma; vein 3-SR of forewing 1.8x length of r; vein SR1+3-SR curved; r arising 1/3rd of the pterostigma; r: 2-SR:S-R1+3-SR= 10:20:112; 1-CU1: 2-CU1: 3-CU1 = 1:42:15; m-cu and cu-a post furcal; length of hind wing 3.5x of its width; 1-M: 1-r-m: 2-SC+R= 12:28:7.

Metasoma: Length of metasoma 3.1x of its width and 2.8x of its height; length of first metasomal tergite 4.3x of its apical width; apical width 2x its basal width; first metasomal tergite smooth apically, medially some striae; dorsope present; spiracles present just middle of first metasomal tergite; second metasomal tergite smooth, long; rest of tergite smooth and sparsely setose; ovipositor very long and pointed, length of ovipositor sheath 0.36x forewing.

Colour: Head reddish-brown, eyes greyish, ocelli yellowish, ocellar area reddish, wings hyaline with brown venation, scape, pedicel, F1–F17 segments reddish-yellow, remaining antennal segments dark brown, legs reddish-yellow except tarsus pale yellow and claw dark brown femur, mandibles yellow with black dentation, maxillary and labial palpi yellowish, pronotum, scutellum, propodeum, first metasomal tergite and remaining terga reddish-yellow, ovipositor yellow and ovipositor sheaths dark brown.

Etymology: The new species is named after the red colour of the body of the type specimen.

Male: Unknown

Host: Unknown

Diagnosis: The new species *Meteorus rubrum* Ahmed & Shamim, sp. nov. closely resembles with *Meteorus dichomeridis* (Wilkinson, 1930). It, however, differs from this species in certain peculiar characters which are as follows:

***Meteorus dichomeridis* Wilkinson, 1930**	***Meteorus rubrum* Ahmed & Shamim, sp. nov.**
Antennal segments 26–28	Antennal segments 38
Vein 3-SR of forewing equal to r	Vein 3-SR of forewing 1.8x length of r
First metasomal tergite 2x its apical width	First metasomal tergite 4.3x its apical width
Face minutely punctate and aciculate	Face rugose and densely setose

Meteorus rubrum Ahmed & Shamim, sp. nov. also closely resembles *Meteorus kotanni* (Maeto, 1986); however, it differs as follows:

***Meteorus kotanni* Maeto, 1986**	***Meteorus rubrum* Ahmed & Shamim, sp. nov.**
Antennal segments 41	Antennal segments 38
Vertex punctate	Vertex smooth and densely setose
Propodeum with median longitudinal carina anteriorly and transverse carina posteriorly	Propodeum entirely reticulate rugose
First metasomal tergite apically reticulate rugose, medially longitudinally striate rugose	First metasomal tergite apically smooth, medially some striae

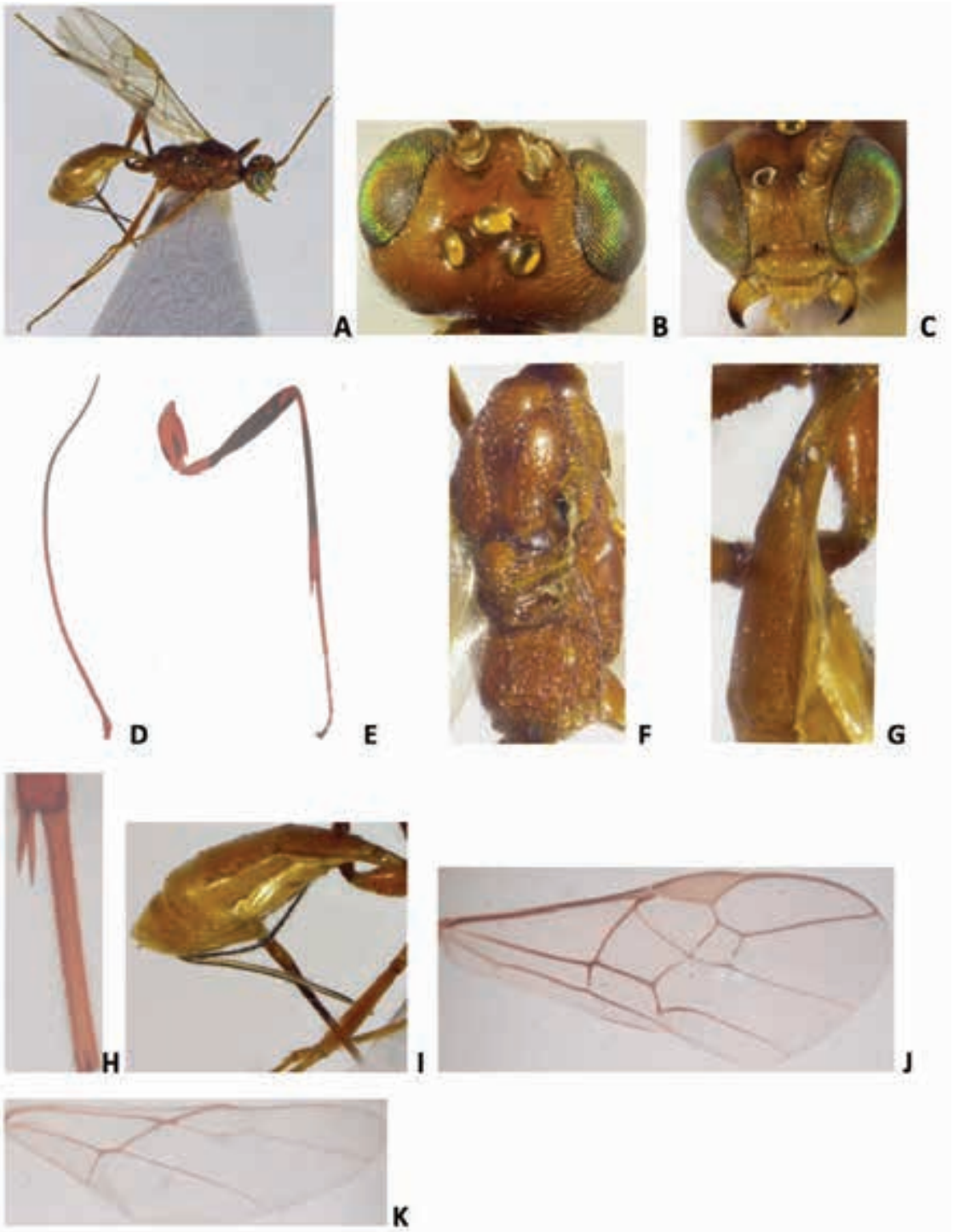

Image 1 A–K. Female *Meteorus rubrum* Ahmed & Shamim, sp. nov.: A—Habitus | B—Dorsal head | C—Frontal head | D—Antenna | E—Hind leg | F—Mesosoma dorso-lateral | G—First metasomal tergite | H—Tibial spurs | I—Metasoma lateral | J—Forewing | K—Hindwing. © Zaheer Ahmed.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18015–18019
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6164.13.3.18015-18019
#6164 | Received 15 May 2020 | Final received 02 August 2020 | Finally accepted 05 March 2021
PLATINUM OPEN ACCESS
SHORT COMMUNICATION

Addition of four woodlice species (Crustacea: Isopoda) to the checklist of Iranian Oniscidea

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Abstract: Four new records of Oniscidea from Iran including *Armadillidium azerbaidzhanum*, *A. nasatum*, *Platyarthrus schoeblii*, and *Armadillo alievi* are provided. Important diagnostic characters of the recorded species are photographed.

Keywords: *Armadillidium*, *Armadillo*, Iran, *Platyarthrus*, terrestrial Isopods, woodlice.

Terrestrial isopods comprise more than 3,700 species with worldwide distribution (Sfenthourakis & Taiti 2015). They have occupied various terrestrial habitats from seashores to the extremely dry environments of deserts (Oliver & Meechan 1993).

The environmental heterogeneity of Iran, hosting a variety of habitats from deserts to dense woodlands, provides rich opportunities for woodlice speciation. Hence, many species of terrestrial isopods are estimated to be present in the country. Existence of *Ligia persica* Khalaji-Pirbalouty & Wägele 2010, adaptated to life in the intertidal zones of Persian Gulf islands, and *Hemilepistus* spp., living in the dry environments of the eastern deserts of Iran, indicates the remarkable variety of habitats and hence, the potentially high diversity of terrestrial isopods adapted to these habitats in the country.

In order to protect biodiversity and to recognise threatened species, it is very important to know what species are present in a continent, a country or smaller area, and exactly where they occur.

Several studies that have been published by Schmalfuss (1986), Kashani et al. (2013, 2016, 2018), Kashani (2014, 2016, 2018), Eshaghi et al. (2015), Kashani & Hamidnia (2016), and Bakhshi et al. (2020) have considerably increased our knowledge of terrestrial isopods of Iran. Kashani (2018) published a comprehensive checklist of all the terrestrial isopods reported from Iran including 45 species belonging to 25 genera and 11 families. Nevertheless, due to the geographic situation of Iran, which is in between the three biogeographic realms (i.e., Palaearctic, Oriental, and Afrotropical faunal regions), it can be expected that there are many new species and new records of these crustaceans are expected to be discovered in the country.

Here we report one genus and four species of the suborder Oniscidea from Iran, all of which are considered

Editor: Anonymity requested. **Date of publication:** 26 March 2021 (online & print)

Citation: Bakhshi, Y., S. Sadeghi, H. Darvishnia & M. Dashan (2021). Addition of four woodlice species (Crustacea: Isopoda) to the checklist of Iranian Oniscidea. *Journal of Threatened Taxa* 13(3): 18015–18019. https://doi.org/10.11609/jott.6164.13.3.18015-18019

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgments: We cordially thank Dr. Ghasem Mohammadi Kashani (Zanjan University) for sending us some hardly accessible papers on terrestrial isopods. We also thank Hossein Bakhshi and Reza Bakhshi for their help during the field trips. Farzaneh Morovat is also thanked for collecting some of the specimens.

to be new records based on their absence in the checklist of the terrestrial isopods of Iran published by Kashani (2018). Images of the whole body and the body parts with diagnostic importance are provided for each of the newly recorded species, so that they can be used for further studies and comparison with other specimens from different regions. According to these findings, the number of known species of the genera *Armadillidium*, *Armadillo*, and *Platyarthrus* in Iran is increased to three, one, and two, respectively.

Genus *Armadillo* is also recorded in Iran for the first time**,** although it seems that the genus is distributed in many parts of the country (unpublished data).

Material and Methods

The present study was conducted during 2015–2019 and a number of woodlice were collected from different parts of Iran. Our new records are from north (Guilan and Mazandaran provinces), northwest (Azarbaijan-e Gharbi Province), west (Kermanshah Province), and south (Fars Province) of Iran. The collected specimens were preserved in 70% ethanol and transferred to the Entomology Research Lab in the Biology Department at Shiraz University. Identification of the specimens conducted based on morphological characters. Images of whole body and body parts with diagnostic importance are provided for each species. Digital photographs of the specimens were taken by a Canon 7D digital camera mounted on a Zeiss stemi11 stereomicroscope and on an Olympus CH40 compound microscope, and the microphotographs were taken using a Tescan Vega3 scanning electron microscope. The studied material is deposited in the Zoological Museum, Collection of Biology Department of Shiraz University (ZM-CBSU).

Results

Order Isopoda Latreille, 1817

Suborder Oniscidea Latreille, 1802

A: Family Armadillidiidae Brandt, 1833

Genus *Armadillidium* Brandt, 1833

Armadillidium azerbaidzhanum Schmalfuss, 1990

Material examined: ZM-CBSU 1282, 22.iv.2015, 7 males & 7 females, Guilan Province, Talesh, 37.75°N, 48.91°E, 206m, leg. H. Darvishnia. ZM-CBSU 1286, 10.ix.2016, 6 males & 3 females, Azarbaijan-e-Gharbi Province, Urmia, near the Urmia Lake, 37.708°N, 45.216°E, 1,276m, leg. Y. Bakhshi & M. Dashan.

The identification of the collected specimens was performed based on the description and line drawings presented by Schmalfuss (1990): pages 5–7; Figures 6, 7, 9–11).

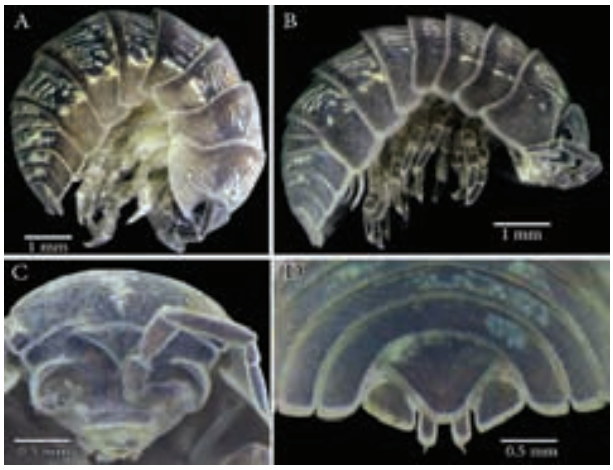

Image 1. *Armadillidium azerbaidzhanum*: A—female habitus, lateral view | B—male habitus, lateral view | C—head, frontal view | D—telson and uropods, dorsal view | © Y. Bakhshi.

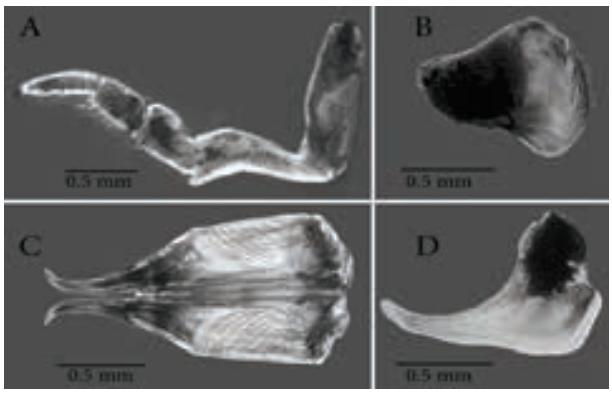

Image 2. *Armadillidium azerbaidzhanum* male appendages: A—pereopod VII | B—pleopod exopodite I | C— pleopod endopodites I | D—pleopod exopodite II | © Y. Bakhshi.

Distribution: Armenia, Azerbaijan, Georgia, Iran (new record).

Remarks: Males are darker in colour and have fewer bright spots than females, especially on the body sides (Image 1). *Armadillidium azerbaidzhanum* is very similar to *A. vulgare* but differs from it by its smaller size and different shape of pleopods I and II, as well as the shape and size of the segments of pereopod VII (Image 2). *A. azerbaidzhanum* has previously been recorded from Caucasus region (Armenia, Azerbaijan, and Georgia) (Schmalfuss 1990). In contrast to *A. vulgare* which is widely distributed in Iran (Kashani 2014), it seems that the distribution area of *A. azerbaidzhanum* is restricted to the northern and northwestern parts of the country.

Armadillidium nasatum Budde-Lund, 1885

Material examined: ZM-CBSU 1289, 23.iv.2015, 7 males & 4 females, Qazvin province, Qazvin-Buin Zahra road, 36.166°N, 50.016°E, 1,227 m, leg. H. Darvishnia. ZM-CBSU 1291, 27.viii.2017, 6 males & 5 females, Mazandaran Province, Tonekabon, 36.816°N, 50.858°E, 15m, leg. Y. Bakhshi. ZM-CBSU 1293, 03.vii.2019, 2 males & 1 female, Fars Province, Shiraz, 29.633°N, 52.533°E, 1,577m, leg. F. Morovat.

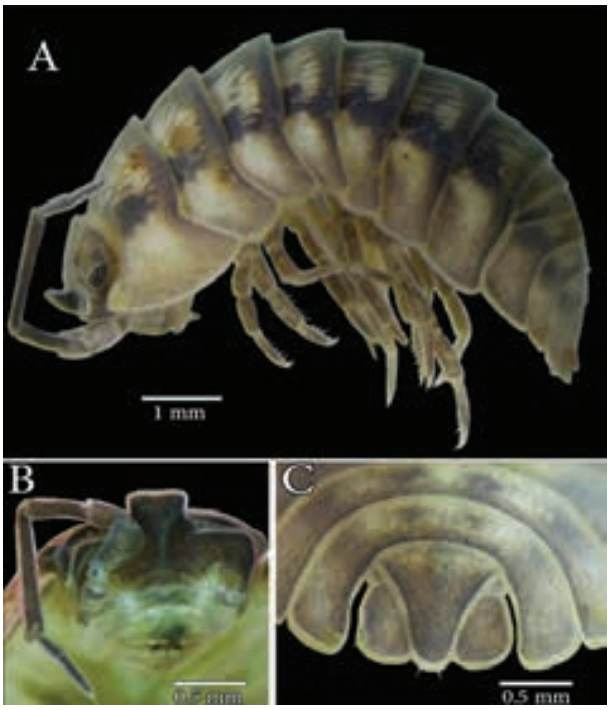

Image 3. ***Armadillidium nasatum*****: A—male habitus, lateral view | B—head, frontal view | C—telson and uropods, dorsal view | © Y. Bakhshi.**

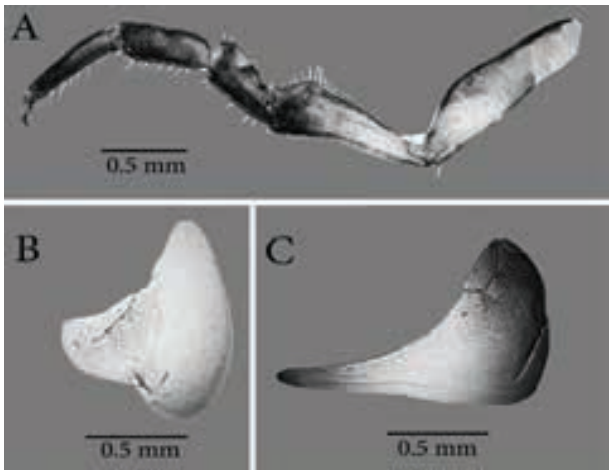

Image 4. ***Armadillidium nasatum*****: A—pereopod VII | B—pleopod exopodite I | C—pleopod exopodite II | © Y. Bakhshi.**

The identification of the collected specimens is performed based on the description and line drawings presented by Oliver & Meechan (1993: pages 88, 98–99, figures 32 D–F, 38)

Distribution: Northern and western Europe (France, Germany, Italy, the Netherlands, Russia, Spain, United Kingdom), Caucasus Mountains, Japan, United States, Iran (new record).

Remarks: The conspicuous upright scutellum of the head (Image 3) and the structure of pleopod exopodite I and pereopod VII of male (Image 4) make *Armadillidium nasatum* easily distinguishable from all other congeneric species. Previous records of *A. nasatum* were mainly from Europe, however, it has probably been introduced in Asia and many other parts of the world. Even though this species is considered to be cosmopolitan (Schmalfuss 2006), it had not been recorded in Iran until now. Some specimens were collected from a garden in Shiraz, which may indicate the possibility of the introduction of this species into the country along with the imported plants.

B: Family Platyarthridae Verhoeff, 1949

Genus *Platyarthrus* Brandt, 1833

***Platyarthrus schoeblii* Budde-Lund, 1885**

Material examined: ZM-CBSU 1273, 19.v.2016, 7 males & 9 females, Kermanshah Province, Sarpole Zahab, 34.633°N, 45.966°E, 855m, leg. Y. Bakhshi & H. Darvishnia. SEM photographs for the collected specimens are presented in images 5 and 6.

The identification of the collected specimens was based on the description and drawings presented by Budde-Lund (1885: pages 200–201) and Vandel (1946: pages 218–223, figures 64–66).

Distribution: Macaronesian Islands; Mediterranean region and the Black Sea coasts.

Remarks: The genus *Platyarthrus* is mainly distributed in the Mediterranean region. *P. schoeblii* is the second species of the genus recorded in Iran. Before the present study, only *P. hoffmannseggii* was reported from the country (Bakhshi & Sadeghi 2019). The specimens were collected in some ant nests under stones.

Our specimens belong to the *Platyarthrus-schoeblii*-complex and show some similarities to *P. schoeblii esterelanus* (or *P. esterelanus*) according to the structure of dorsal sculptures (Image 5) and the male pleopod endopodite I (Images 6E,F).

The systematics of the *Platyarthrus-schoeblii*-complex is not clear. Some members of this species-complex are considered either as subspecies by some authors (e.g., *P. s. esterelanus*) or as a distinct species

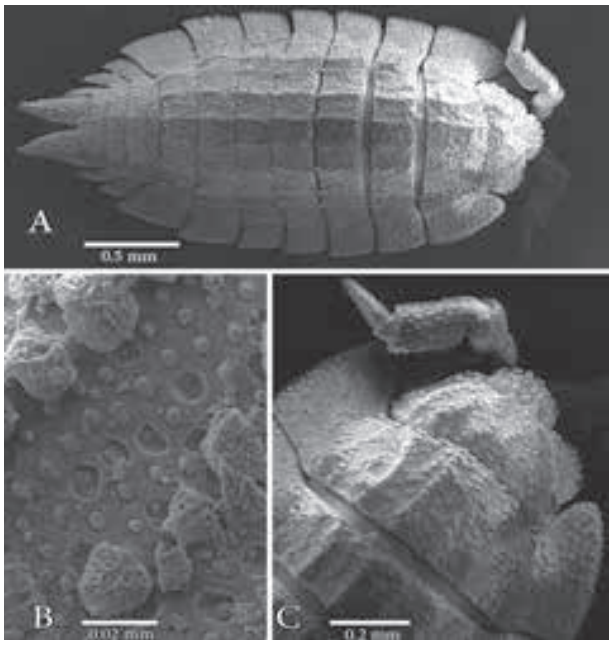

Image 5. *Platyarthrus schoeblii* male: A—whole body, dorsal view | B—dorsal scale setae (enlarged) | C—head and first pereonite, dorsal view | © Y. Bakhshi.

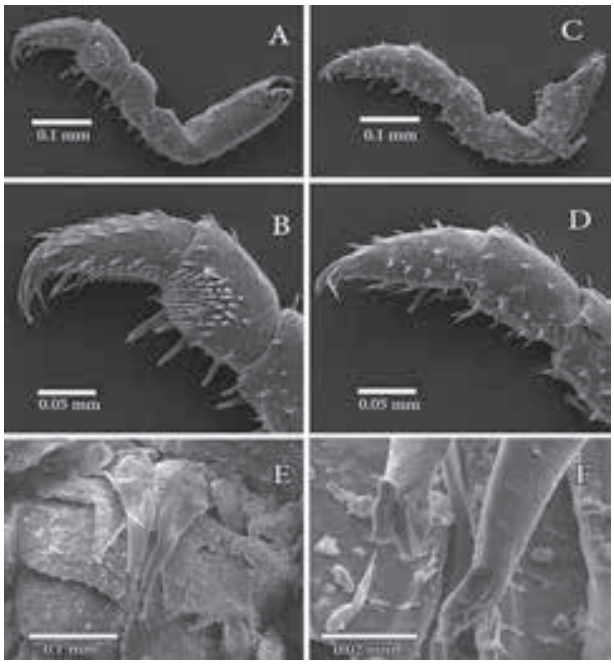

Image 6. *Platyarthrus schoeblii* male appendages: A—pereopod I | B—pereopod I distal segments | C—pereopod VII | D—pereopod VII distal segments | E—pleopods ventral view | F—apex of pleopod endopodites I | © Y. Bakhshi.

by others (e.g., *P. esterelanus*) (Schmalfuss, 2003). Therefore, more morphological and molecular studies are required to clarify the systematic situation of this species complex.

C: Family Armadillidae Verhoeff, 1917
Genus *Armadillo* Latreille, 1802
***Armadillo alievi* Schmalfuss, 1990**

Material examined: ZM-CBSU 1280, 23.iv.2015, 3 males & 2 females, Qazvin Province, Qazvin-Buin Zahra road, 36.166°N, 50.016°E, 1,227m, leg. H. Darvishnia. The identification of the collected specimens was based on the description and drawings presented by Schmalfuss (1990: figures 38–41). Photographs of whole body and male appendages are presented in image 7.

Distribution: Azerbaidjan**,** northwestern Iran (new record).

Remarks: *Armadillo alievi* has previously been recorded in Azerbaidjan, the type locality of the species. Some other species of the genus *Armadillo* have also been reported from the neighbouring countries of Iran such as Iraq and Turkey (Schmalfuss 2003). Therefore, although *Armadillo alievi* is considered as the first representative of the genus *Armadillo* in Iran, several species of the genus are expected to be found in the country.

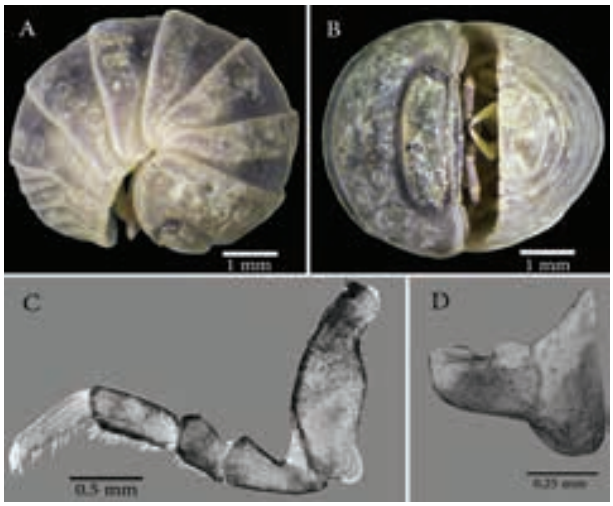

Image 7. *Armadillo alievi* male: A—lateral view of body | B—frontal view of body, showing head, pereonite I, telson and uropods | C—pereopod VII | D—pleopod exopodite I | © Y. Bakhshi.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18020–18029
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.5669.13.3.18020-18029
#5669 | Received 01 January 2020 | Final received 02 March 2021 | Finally accepted 07 March 2021
PLATINUM OPEN ACCESS
SHORT COMMUNICATION

Catalogue of selected insect groups of Lalwan Community Reserve and Ranjit Sagar Conservation Reserve, Punjab, India

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Abstract: We present the first documentation of the insect fauna of Lalwan Community Reserve and Ranjit Sagar Conservation Reserve, Punjab. The survey was conducted in the months of May and June 2019. Selected insect groups were focused on for the rapid documentation of the entomofauna. Overall, we recorded 91 species of insects belonging to the orders Lepidoptera, Coleoptera, and Odonata. A total of 68 species including 46 species of order Lepidoptera, nine species of Odonata, and 13 species of Coleoptera were reported from Lalwan Community Reserve. Thirty-seven species consisting of 23 species of Odonata and 14 species of Lepidoptera were recorded from Ranjit Sagar Conservation Reserve, Punjab.

Keywords: Coleoptera, diversity, entomofauna, Lepidoptera, Odonata.

A healthy ecosystem reveals the diversity and community structure of the insect groups in itself (Fagundes et al. 2011). Biodiversity surveys provide fundamental information needed for conservation planning, protected area justification and design, and development of management plans (Spector & Forsyth 1998). India is on the list as one of the major biodiversity rich countries of the world, due to the presence of a wide range of habitats from alpine to tropical ecosystems and freshwater to marine, desert, and island ecosystems (Ghosh 1996). According to studies conducted by Ghosh in the years 1990, 1994, and 1996, 2% of the total global space resides in India and in terms of biodiversity it inhabits about 7% of faunal biodiversity globally. Among all the fauna on Earth class Insecta is the most flourishing, these appeared 3 billion years ago and spread all over the world due to their ability to survive in any habitat and extreme conditions; hence considered as indicators of changes happening in nature (Harrington & Stork 1995; Gullan & Cranston 1996). Insects are the most diverse animal group present on earth and show an extreme level of adaptability probably in all kinds of habitats (Harrington & Stork 1995; Landres et al. 1988).

Insects are the largest group among animals regarding their global presence (10,53,578 species); India is also rich in insect diversity with 65,047 species (Chandra et al. 2018), occupying several ecological niches, being considered very important in the dynamics of natural ecosystems (Borror et al. 1992; Kim 1993; Gullan & Cranston 1996; Thomazini & Thomazini 2000). Coleoptera (beetles) are the largest order of insects, with about 400,000 species worldwide, representing 30% of animals and about 40% of all insects (Lawrence & Britton 1991; Lawrence & Newton 1995; Costa 2000). About 180,000 species of Lepidoptera have been described in the world which comprise of moths and butterflies. A total of 1,439 species of butterflies have been described from India so far. They play an

Editor: K.A. Subramanian, Zoological Survey of India, Chennai, India.
Date of publication: 26 March 2021 (online & print)
Citation: Singh, A.P., A. Chandra, V.P. Uniyal & B.S. Adhikari (2021). Catalogue of selected insect groups of Lalwan Community Reserve and Ranjit Sagar Conservation Reserve, Punjab, India. *Journal of Threatened Taxa* 13(3): 18020–18029. https://doi.org/10.11609/jott.5669.13.3.18020-18029

Funding: Study was funded by Punjab Forest Department.
Competing interests: The authors declare no competing interests.
भारतीय वन्यजीव संस्थान
Wildlife Institute of India
Acknowledgements: Authors are thankful to the director Wildlife Institute of India for providing the necessary support to carry out this study and to the Punjab Forest Department for providing necessary funds to carry out the study.

important role in pollinating flowering plants. Odonata comprises carnivorous insects, dragonflies (Anisoptera) and the damselflies (Zygoptera). Odonates comprise 6,233 species in 685 genera globally, India has 486 species, about 50 subspecies in 151 genera and 18 families (Subramanian & Babu 2017). Dragonflies and damselflies are very good indicators of freshwater.

Sharma & Joshi (2009) documented the butterflies in district Hoshiarpur from Dholbaha Dam. Bhardwaj et al. (2017) documented the biodiversity of Siswan Reserve, Punjab in which 169 species of insects were reported. Singh et al. (2018) reported the coleopteran fauna of the Siswan Reserve, Punjab. The present study reveals the Lepidoptera, Coleoptera, & Odonata fauna of the Lalwan Community Reserve and Lepidoptera & Odonata fauna of Ranjit Sagar Conservation Reserve, Punjab for the first time.

Study Area

Lalwan Community Reserve (LCR) is situated in Tehsil Garshakar in district Hoshiarpur, Punjab. Ranjit Sagar Conservation Reserve (RSCR) is known for the Ranjit Sagar Dam, also known as the Thein Dam, constructed by the Government of Punjab on the Ravi River (Figure 1). RSCR is situated on the border of two states of India, Jammu & Kashmir and Punjab. Insect assessment was carried out only in the Punjab portion of the RSCR.

Methods

Lepidoptera, Odonata, & Coleoptera orders were focused in LCR, however only Lepidoptera and Odonata were focused in RSCR. The insect sampling survey was done through the water streams of forests of LCR and on the bank of the RSCR Lake. A total of 17 points were selected at 1,000-m intervals for sampling in the LCR whereas 10 points were selected at the RSCR. Sampling was done both at day (09.00–18:00 h) and night (20:00–22:00 h). Sweep netting was performed for insects under order Lepidoptera, Hymenoptera, & Odonata. Light trapping method was applied during the evening and night sampling to collect insects like Lepidoptera and Coleoptera. Hand picking method was applied for insects under order Coleoptera. Insects were photographed and a few were also collected for their proper key identification. Odonates were identified using published literature (Andrew et al. 2008; Subramaniam 2009; Nair 2011) and web sources. Butterflies were identified with published literature (Uniyal 2004; Talbot 1939, 1947; Singh 2011) and web sources. Moths using (Hampson 1892–1896; Zolotuhin & Pinratana 2005; Pinratana & Cerny 2009; Nieukerken et al. 2011). Beetles were identified with the published literature (Andrewes 1929; Sewak 2009; Chandra & Gupta 2013; Chandra 2018).

Results and Discussion

A total of 91 species (Table 1) belonging to 19 families were reported (Figure 2) including 68 species from LCR and 37 species from RSCR, which were reported for the first time from the regions. LCR holds the diversity of 46 species of order Lepidoptera, nine species of Odonata, and 13 species of Coleoptera. RSCR holds the diversity of 23 species of Odonata and 14 species of Lepidoptera (Figure 3). Photographs of all the species reported from these two regions are presented in Images 1–4.

Biodiversity conservation issues mostly focus on the ecological impact of management practices and their aim is to provide a practical background for sustainable biodiversity management. Such a study was done in the

Figure 1. Map represents the two study areas in Punjab State.

Table 1. Catalogue of species recorded from Lalwan Community Reserve and Ranjit Sagar Conservation Reserve.

	Family	Genus	Species	Author & year of description	Common name	Location
	Lepidoptera					
1	Hesperiidae	*Pelopidas*	*sinensis*	Mabille, 1877	Chinese Branded Swift	LCR, RSCR
2		*Sarangesa*	*dasahara dasahara*	Moore,1866	Indian Common Small Flat	LCR
3		*Tarucus*	*nara*	Kollar, 1848	the striped Pierrot	RSCR
4	Lycaenidae	*Albulina*	sp.			LCR
5		*Anthene*	*emolus emolus*	Godart, 1824	Bengal Common Ciliate Blue	LCR
6		*Castalius*	*rosimon*	Fabricius, 1775	the common Pierrot	LCR
7		*Celatoxia*	*albidisca*	Moore, 1884	White disc Hedge blue	LCR
8		*Curetis*	*acuta*	Moore, 1877	Acute Sunbeam	LCR
9		*Tajuria*	*cippus*	Fabricius, 1798	Indian Peacock Royal	LCR
10	Nymphalidae	*Acraea*	*violae*	Fabricius, 1775	Tawny Coster	RSCR
11		*Ariadne*	*merione*	Cramer, 1777	Common Castor	LCR, RSCR
12		*Cyrestis*	*thyodamas*	Boisduval, 1836	Map Butterfly	LCR
13		*Danaus*	*chrysippus*	Linnaeus, 1758	Plain Tiger	LCR
14		*Euploea*	*mulciber*	Cramer, 1777	the striped blue crow	RSCR
15		*Euploea*	*core*	Cramer, 1780	Common Crow	LCR, RSCR
16		*Hypolimnas*	*bolina*	Drury, 1773	the great eggfly, common eggfly	LCR, RSCR
17		*Junonia*	*lemonias*	Linnaeus, 1758	lemon pansy	LCR, RSCR
18		*Junonia*	*almana*	Linnaeus, 1758	Peacock Pansy	LCR
19		*Junonia*	*hierta hierta*	Fabricius, 1798	Oriental Yellow Pansy	LCR
20		*Junonia*	*iphita*	Cramer, 1779	Chocolate Pansy	LCR, RSCR
21		*Junonia*	*orithya ocyale*	Hübner, 1819	Dark Blue Pansy	LCR
22		*Lethe*	*europa*	Fabricius, 1775	Bamboo Treebrown	LCR
23		*Neptis*	*hylas*	Linnaeus, 1758	Common Sailer	LCR
24		*Parantica*	*aglea*	Stoll, 1782	the glassy tiger	RSCR
25		*Phalanta*	*phalantha*	Drury, 1773	Common Leopard	LCR, RSCR
26		*Tirumala*	*septentrionis*	Butler, 1874	Dark Blue Tiger	LCR, RSCR
27	Papilionidae	*Graphium*	*cloanthus cloanthus*	Westwood, 1841	Himalayan glassy bluebottle	LCR
28		*Papilio*	*polytes*	Linnaeus, 1758	Indian Common Mormon	LCR, RSCR
29	Pieridae	*Belenois*	*aurota aurota*	Fabricius, 1793	Indian Pioneer	LCR
30		*Catopsilia*	*pomona*	Fabricius, 1775	Lemon Emigrant	LCR, RSCR
31		*Eurema*	*brigitta*	Stoll, 1780	Small Grass Yellow	LCR
32		*Ixias*	*marianne*	Cramer, 1779	White Orange-tip	LCR
33		*Pieris*	*canidia*	Sparrman, 1768	Asian Cabbage White	LCR
34	Crambidae	*Agrotera*	*scissalis*	Walker, 1865		LCR
35		*Cnaphalocrocis*	*medinalis*	Guenée, 1854		LCR
36		*Conogethes*	*punctiferalis*	Guenée, 1854		LCR
37		*Diaphania*	*indica*	Saunders, 1851		LCR
38		*Omiodes*	sp.			LCR
39		*Orphanostigma*	*abruptalis*	Walker, 1859		LCR
40	Erebidae	*Barsine*	*orientalis*	Černý Pinratana, 2009		LCR
41		*Arctornis*	sp.			LCR
42		*Spilosoma*	*lutea*	Hufnagel, 1766		LCR
43		*Lymantria*	sp.			LCR

	Family	Genus	Species	Author & year of description	Common name	Location
44	Geometridae	*Scopula*	sp.			LCR
45		*Scopula*	sp. 1			LCR
46		*Nemoria*	sp.			LCR
47		*Hypomecis*	sp.			LCR
48		*Idaea*	sp.			LCR
49	Drepanidae	*Tridrepana*	*albonotata*	Moore, 1879		LCR
50	Limacodidae	*Thosea*	sp.			LCR
	Odonata					
51	Chlorocyphidae	*Libellago*	*lineata*	Burmeister, 1839	River heliodor	RSCR
52	Coenagrionidae	*Agriocnemis*	*lacteola*	Selys, 1877	Milky Dartlet	RSCR
53		*Amphiallagma*	*parvum*	Selys, 1876	Little Blue or Azure Dartlet	RSCR
54		*Ceriagrion*	*cerinorubellum*	Brauer, 1865	Orange-tailed Marsh	RSCR
55		*Ceriagrion*	*coromandelianum*	Fabricius, 1798	Coromandel Marsh Dart and Yellow Waxtail	RSCR
56		*Ceriagrion*	*olivaceum*	Laidlaw, 1914	Rusty Marsh Dart	RSCR
57		*Copera*	*marginipes*	Rambur, 1842	Yellow Bush Dart	RSCR
58		*Paracercion*	*calamorum*	Ris, 1916	Dusky Lilysquatter	RSCR
59		*Pseudagrion*	*microcephalum*	Rambur, 1842	The Blue Riverdamsel	RSCR
60	Gomphidae	*Ictinogomphus*	*rapax*	Rambur, 1842	Common Clubtail	LCR
61	Libellulidae	*Acisoma*	*panorpoides*	Rambur, 1842	Asian Pintail, Trumpet Tail	RSCR
62		*Orthetrum*	*glaucum*	Brauer, 1865	Blue Marsh Hawk	RSCR
63		*Brachydiplax*	*farinosa*	Krüger, 1902	Black-tailed Dasher	LCR
64		*Brachythemis*	*contaminata*	Fabricius, 1793	Ditch Jewel	LCR, RSCR
65		*Brachythemis*	sp.			LCR
66		*Bradinopyga*	*geminata*	Rambur, 1842	Granite Ghost	RSCR
67		*Crocothemis*	*servilia*	Drury, 1770	scarlet Skimmer or Ruddy Marsh Skimmer	RSCR
68		*Hydrobasileus*	*croceus*	Brauer, 1867	Amber-winged Marsh Glider	RSCR
69		*Indothemis*	*carnatica*	Fabricius, 1798	Black Marsh Skimmer	LCR, RSCR
70		*Neurothemis*	*fulvia*	Drury, 1773	Fulvous Forest Skimmer	LCR, RSCR
71		*Neurothemis*	*tullia*	Drury, 1773	Pied Paddy Skimmer	RSCR
72		*Orthetrum*	*luzonicum*	Brauer, 1868	Marsh Skimmer	LCR
73		*Orthetrum*	*pruinosum*	Burmeister, 1839	Crimson-tailed Marsh Hawk	RSCR
74		*Orthetrum*	*sabina*	Drury, 1770	Slender Skimmer or Green Marsh Hawk	LCR, RSCR
75		*Orthetrum*	*triangulare*	Selys, 1878	Black-tailed Dasher	RSCR
76		*Rhodothemis*	*rufa*	Rambur, 1842	Rufous Marsh Glider	LCR
77		*Rhyothemis*	*variegata*	Linnaeus, 1763	Common Picture Wing or Variegated fFutterer	RSCR
78		*Trithemis*	*aurora*	Burmeister, 1839	Crimson Marsh Glider	RSCR
	Coleoptera					
79	Meloidae	*Hycleus*	*pustulata*	Thunberg, 1791		LCR
80	Coccinellidae	*Harmonia*	*dimidiata*	Fabricius, 1781		LCR
81	Carabidae	*Pheropsophus*	*verticalis*	Dejean, 1825		LCR
82		*Pheropsophus*	sp.			LCR
83	Histeridae	*Carcinops*	*pumilio*	Dejean, 1825		LCR

	Family	Genus	Species	Author & year of description	Common name	Location
84	Scarabidae	*Copris*	sp.			LCR
85		*Onitis*	sp.			LCR
86		*Onitis*	*singhalensis*	Lansberge, 1875		LCR
87		*Onitis*	*niger*	Wiedemann, 1819		LCR
88		*Onitis*	*castaneous*	Redt, 1848		LCR
89		*Onthophagus*	sp.			LCR
90		*Oniticellus*	*cinctus*	Fabricius, 1775		LCR
91		*Onthophagus*	*bonasus*	Fabricius, 1775		LCR

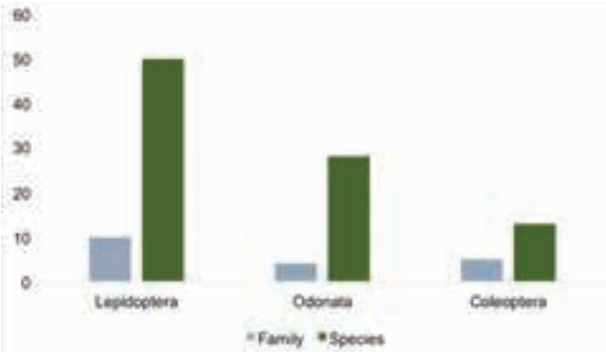

Figure 2. Overall number of insect families and species reported from the regions.

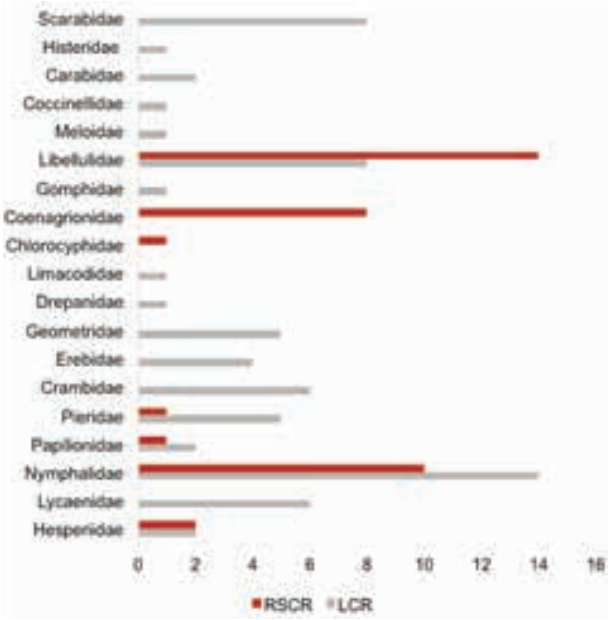

Figure 3. Number of species of each family reported from LCR and RSCR.

Siswan Reserve, Punjab which incorporated 169 species of insects to the insect fauna of Punjab (Bhardwaj et al. 2017; Singh et al. 2018) and the present study, conducted in LCR and RSCR has made a significant contribution towards increasing knowledge of insect species distributions in this area. These areas have extremely high entomofauna diversity with a total of 91 species of insects. Furthermore, the study unfolds new distribution records for all species found in this area.

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Images 1–24. 1—*Pelopidas sinensis* | 2—*Sarangesa dasahara dasahara* | 3—*Tarucus nara* | 4—*Albulina* sp. | 5—*Anthene emolus emolus* | 6—*Castalius rosimon* | 7—*Celatoxia albidisca* | 8—*Curetis acuta* | 9—*Curetis acuta* | 10—*Acraea violae* | 11—*Ariadne merione* | 12—*Cyrestis thyodamas* | 13—*Danaus chrysippus* | 14—*Euploea mulciber* | 15—*Euploea core* | 16—*Hypolimnas bolina* | 17—*Junonia lemonias* | 18—*Junonia almana* | 19—*Junonia hierta hierta* | 20—*Junonia iphita* | 21—*Junonia orithya ocyale* | 22—*Lethe europa* | 23—*Neptis hylas* | 24—*Parantica aglea*. © Amar Paul Singh.

Images 25–48. 25—*Phalanta phalantha* | 26—*Tirumala septentrionis* | 27—*Graphium cloanthus cloanthus* | 28—*Papilio polytes* | 29—*Belenois aurota aurota* | 30—*Catopsilia pomona* | 31—*Eurema brigitta* | 32—*Ixias marianne* | 33—*Pieris canidia* | 34—*Agrotera scissalis* | 35—*Cnaphalocrocis medinalis* | 36—*Conogethes punctiferalis* | 37—*Diaphania indica* | 38—*Omiodes* sp. | 39—*Orphanostigma abruptalis* | 40—*Barsine orientalis* | 41—*Arctornis* sp. | 42—*Spilosoma lutea* | 43—*Lymantria* sp. | 44—*Scopula* sp. | 45—*Scopula* sp. | 46—*Nemoria* sp. | 47—*Hypomecis* sp. | 48—*Idaea* sp. © Amar Paul Singh.

Images 49–72. 49—*Tridrepana albonotata* | 50—*Thosea* sp. | 51—*Libellago lineata* | 52—*Agriocnemis lacteola* | 53—*Amphiallagma parvum* | 54—*Ceriagrion cerinorubellum* | 55—*Ceriagrion coromandelianum* | 56—*Ceriagrion olivaceum* | 57—*Copera marginipes* | 58—*Paracercion calamorum* | 59—*Pseudagrion microcephalum* | 60—*Ictinogomphus rapax* | 61—*Acisoma panorpoides* | 62—*Orthetrum glaucum* | 63—*Brachydiplax farinosa* | 64—*Brachythemis contaminata* | 65—*Brachythemis* sp. | 66—*Bradinopyga geminate* | 67—*Crocothemis servilia* | 68—*Hydrobasileus croceus* | 69—*Indothemis carnatica* | 70—*Neurothemis fulvia* | 71—*Neurothemis tullia* | 72—*Orthetrum luzonicum.* © Amar Paul Singh.

Images 73–91. 73—*Orthetrum pruinosum* | 74—*Orthetrum sabina* | 75—*Orthetrum triangulare* | 76—*Rhodothemis rufa* | 77—*Rhyothemis variegate* | 78—*Trithemis aurora* | 79—*Hycleus pustulata* | 80—*Harmonia dimidiate* | 81—*Pheropsophus verticalis* | 82—*Pheropsophus* sp. | 83—*Carcinops pumilio* | 84—*Copris* sp. | 85—*Onitis* sp. | 86—*Onitis singhalensis* | 87—*Onitis niger* | 88—*Onitis castaneous* | 89—*Onthophagus* sp. | 90—*Oniticellus cinctus* | 91—*Onthophagus bonasus.* © Amar Paul Singh.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18030–18034
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.5157.13.3.18030-18034
#5157 | Received 09 June 2019 | Final received 12 November 2020 | Finally accepted 05 March 2021
PLATINUM OPEN ACCESS
SHORT COMMUNICATION

Potential phytophagous insects of *Pteridium revolutum* (Blume) Nakai, an invasive fern

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Abstract: The article reports an observation on the phytophagous behaviour by the insect larvae of two insect species on a fern, *Pteridium revolutum*, which is fast emerging as an invasive plant species threatening local biodiversity and wildlife in Kerala State, India.

Keywords: Biological control, phytophagous nature, *Pteridium*, Western Ghats.

Bracken ferns (genus *Pteridium*) represent an ancient species complex with a natural worldwide distribution (Der et al. 2009). Notorious as weeds because of its exceptional ability to grow rhizomatously in dense patches, these ferns are widely reported to overgrow in open fields and pastures (Tryon 1941; Holm et al. 1997). Invasiveness of these clonally growing ferns is attributed to their vigorous vegetative propagation ability and genetic variability (Zhou et al. 2014). *Pteridium revolutum* (Blume) Nakai has reported distribution in diverse ecosystems in India, Sri Lanka, China, Taiwan, southern Japan, Myanmar, the Philippines, Thailand, throughout southeastern Asia, New Guinea, and Australia (Ranil et al. 2010; Deepa et al. 2013). In tropical and subtropical areas of Asia, above 1,000m, *P. revolutum* is perennial with fronds that grow from the robust underground rhizomes, reaching over 1m in height (Zheng et al. 2008). In Chinese medicine, rhizomes of this fern have uses and the fronds are regarded to be attractive to the landscape (Zhang & Zhang 1986).

Toxic effects on herbivores

Many workers like Smith (1990) and Taylor (1990) have reported that in China, the Bracken Fern *Pteridium* sp. is a very common plant and is often browsed by domestic herbivores, developing several syndromes. Enzootic haematuria, the clinical name of the urinary bladder neoplasia of ruminants (bovine enzootic haematuria), tends to occur persistently in localized bracken infested regions throughout the world. In China, enzootic haematuria of cattle was observed in almost all the provinces where *P. revolutum* occurred, but the disease has not been reported outside of these regions (Leren 1989; Xu 1992). Furthermore, in areas where enzootic haematuria was found, the disease usually occured in highland or mountainous areas at 950–2,000 m where conditions are suitable for the growth of *P. revolutum* (Xu 1986). Consumption of this fern has also been reported to cause urinary bladder cancer in ruminants. It is also associated with carcinoma of the upper digestive tract of cattle, where it is believed to be caused by the malignant transformation of the bovine papilloma (Jarrett 1987).

Editor: Anonymity requested. **Date of publication:** 26 March 2021 (online & print)

Citation: Arjun, M.S. & S. Gopakumar (2021). Potential phytophagous insects of *Pteridium revolutum* (Blume) Nakai, an invasive fern. *Journal of Threatened Taxa* 13(3): 18030–18034. https://doi.org/10.11609/jott.5157.13.3.18030-18034

Funding: Self funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors gratefully acknowledge the contributions by Dr. Mani Chellapan, Professor and Head, Department of Agricultural Entomology of College of Horticulture, KAU P. O. Thrissur in identifying the insect larvae.

The major carcinogen of bracken has been identified as Ptaquiloside, a norsesquiterpenoid glycoside (Niwa et al. 1983; Hirono et al. 1984). This readily undergoes glucose elimination to form an unstable conjugated dieneone intermediate capable of alkylating amino acids and DNA (Fletcher et al. 2011). The mutagenicity (Nagao et al. 1989), clastogenicity (Matsuoka et al. 1989), and carcinogenicity (Hirono et al. 1984) of ptaquiloside have been well demonstrated. Bracken has also been associated with livestock poisoning causing bone marrow damage leading to a fatal hemorrhagic disease of cattle ("Bracken" poisoning), and "bracken staggers" of horses (an effect of thiaminase). Fenwick (1989) had drawn attention to the possibility of indirect consumption of the Bracken carcinogen which may cause or increase the risk of cancer in man.

Image 1. Larvae of *Spilosoma obliqua* (5th instar stage).

Pteridium revolutum

Rhizomes long-creeping, hairy, subterranean. Stipes and rachises dull yellow brown, bearing abundant non-glandular hairs, stipes 25–60 cm long, 3–6 mm diameter, hard. Laminae broadly ovate or triangular to broader than long, 100 x 30–90 cm, 3-pinnate at base, leathery, dull light green on both surfaces, not mealy on underside. Primary pinnae arising at narrow angles to rachis, the longest 18–60 x 8–45 cm. Secondary pinnae arising at wide angles, the longest 4–25 x 1–4 cm; midribs of primary and secondary pinnae lacking free lobes or wings. Tertiary pinnae all equal in length on each secondary pinna, the longest 0.6–2.5 x 0.3–0.5 cm. Ultimate segments linear, slightly falcate, acute, entire, adnate. Upper lamina surface sparsely hairy along midribs, lower with dense, colourless, spreading, non-glandular hairs throughout. Reflexed lamina margins protecting sori membranous, fimbriate and hairy (Brownsey 1989).

Image 2. Final instar stage of *T. catamitus* larvae.

Natural enemies on *Pteridium revolutum*

Generally, the fern is considered unpalatable to many animal and insect species due to the presence of toxic secondary metabolites like ptaquiloside, however, we observed two "natural insect feeders" relishing on bracken population in the Chembra and Thirunelly areas in Wayanad District, Kerala State, India. Similar observations could also be noted at Thrissur District (Vazhachal high altitude region) and Gavi (Periyar Tiger Reserve area) in Kerala State, India. During a survey on the distribution of *Pteridium* in Kerala, insect larvae seen feeding on this fern were collected and carried to the lab for identification. The feeding nature, extent of damage caused etc were carefully observed and recorded.

Image 3. Adult of *T. catamitus*.

The collected specimens were later identified as the larvae of two insect species namely, *Spilosoma obliqua* (Lepidoptera: Arctiidae) and *Tetragonus catamitus* (Callidulidae) with the help of insect taxonomists at Kerala Agricultural University (KAU), Kerala State, India.

Spilosoma obliqua

Spilosoma obliqua Walker (Syn. *Diacrisia obliqua*) (Lepidoptera: Arctiidae), commonly known in Asia as the Bihar hairy caterpillar, is a sporadic but polyphagous plant pest that occurs in Bangladesh, Myanmar, India, Pakistan, and Sri Lanka (Singh & Sehgal 1992). The larvae of this species were found feeding on the frond of the bracken fern in the observed areas.

According to Warad & Kalleshwara (2017), the young larvae are translucent light yellow with dark big head (Plate1). The larval body has number of long hairs arising from dark coloured tubercles. Once fully grown, it is more stout and cylindrical with conspicuous dark anterior and posterior patches. Pupation occurs in the soil. The adults are medium sized brown moths and have pink abdomen with wings pinkish with numerous black spots. The antennae and legs are light brown. The average longevity of the adult male is 4–5 days with an average of 4.40 days. The female is bigger than the male. The abdomen of female is blunt, while the abdomen of male is narrower and pointed.

Tetragonus catamitus

T. catamitus, though easily identifiable, are difficult to observe in the field but have been reported from Kerala (Sondhi et al. 2018). Since the larvae of *T. catamitus* feed on ferns, they are also known as Fern Moth. Holloway (1998) also mentions that it hosts on genus *Drynaria* and further mentioned that *T. catamitus* in Hong Kong hosts on *Pteridium* (unpublished Initial Environmental Examination Report).

Their eggs are very flat, scale-like (Holloway 1998). Eggs are laid on the underside of fronds or the young stalk of the host plant. Larvae start feeding from the tip of the pinnae and it seems that their strong mandibles help them to eat the central veins. The head and first thoracic segment of the larvae are black and they have well-developed, chitinous, shiny, black prothoracic shields, which are separated by a median green line. The same line splits into two at the base of the head carapace and extends towards the forehead forming a 'V' shaped mark. Larvae have grass green, translucent bodies. The head of the observed specimen had two symmetrical pale-whitish triangular patches besides the 'V' shaped marking. The head and prothoracic shield on the first thoracic bore several whitish, translucent bristles of various sizes. The pupa is a medium-sized cocoon of an elongated narrow ovate shape, chocolate brown in colour; with a prominent head, which is thickest in the middle, a parallel-sided abdomen forms a cone at the last four segments.

Image 4. Damage caused by *T. catamitus*.

Image 5. Larvae inside the frond.

Potential bio-control agents of Bracken Fern

Even though Bracken Fern's foliage has been reported to possess toxicity, we noticed profuse feeding by these two insect larvae in Wayanad District, Kerala State, India. The frond which was being eaten by these two larvae was neither juvenile nor too mature. While *T. catamitus* larvae were observed as feeding on both the veins and leafy portions, *S. obliqua* were avoiding the veins and feeding only on the leaf portion. *S. obliqua* larvae also left a net-like structure around the frond on which it fed. We noticed that *S. obliqua* larvae created more damage compared to *T. catamitus* larvae. The feeding pattern of

Image 6 . *S. obliqua* feeding frond of *P. revolutum* at Chembra, Wayanad, Kerala.

both the larvae was also noticeably different. The larva of *S. obliqua* seems to be concentrating on one frond at a time. As they could not chew the whole frond, some pinnules were left unaffected by the larvae. On the other hand, *T. catamitus* fed at random. Further, the larvae of *T. catamitus* were observed to use the fern frond to make pupa and finally to moth. *S. obliqua* used the fern only for feeding and no sign of any pupa formation in the frond could be seen. The net-like structure caused by the *S. oblique* could make the frond vulnerable in case of forest fire.

Conclusion

We have observed the 'invasiveness' of the Bracken or Eagle Fern *Pteridium revolutum* in the forest ecosystems of Wayanad, Thrissur, and Pathanamthitta districts of Kerala State, India. The threat of this fern is more in the higher altitudes of the Western Ghats landscape, where the unique grassland ecosystem thrives. The phytotoxicity of this 'weed' and its impact on native flora and foraging fauna, including wild herbivores must be researched and conclusions drawn to shape their management strategies. As *P. revolutum* possess a long, wide creeping rhizome, its mechanical or physical method of management has severe limitations. On the other hand, any disturbance to its root zone will help the weed to establish more aggressively. *P. revolutum* is also highly resistant to drought and fire, which is another favourable trait of its invasiveness. In the light of these, the potential role of the larvae of *Spilosoma oblique* (Lepidoptera: Arctiidae) and *Tetragonus catamitus* (Callidulidae) to manage this invasive fern merits immediate consideration.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18035–18038
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6609.13.3.18035-18038
#6609 | Received 24 August 2020 | Final received 18 February 2021 | Finally accepted 20 February 2021
PLATINUM OPEN ACCESS

NOTE

Freshwater medusae *Limnocnida indica* Annandale, 1911 in the Cauvery Wildlife Sanctuary, Dubare Reserve Forest and Shivanasamudram in Karnataka, India, with a commentary note on the exotic *Craspedacusta sowerbii* Lankester, 1880

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There are over 20 species of freshwater medusae belonging to six genera found across the world, however, the taxonomy of more than half of them are uncertain (Jankowski 2001). Of these, four genera have been reported from India, *Limnocnida*, *Craspedacusta*, *Mansariella*, and *Keralika*. Freshwater medusae are severely understudied globally (Ahmad et al. 1987; Dumont 1994) and lack conservation importance. For instance, more than 100 years after their discovery, none of the Limnomedusa are assessed on the IUCN Red List of Threatened Species. The most popular hypothesis to the origin of the freshwater medusae is their evolution from a common ancestor from the Tethys Sea (Dumont 1994) which later adapted to a freshwater form (Stadel 1961) and dispersed across landmasses. In India, Limnomedusae were first believed to have dispersed westward from the Bay of Bengal to the Western Ghats and then northward to the Himalaya (Rao 1931). Ahmad et al. (1987), however, disagree, proposing that the dispersal of the Limnomedusae was in a southwardly direction starting from the Himalaya; evidenced by the presence of *Mansariella lacustris* which is endemic to an isolated lake in the Himalayan region (Malhotra et al. 1976).

Two genera of Limnomedusae are of interest to this note, i.e., *Limnocnida* and *Craspedacusta*. The genus *Limnocnida* has three confirmed species in India, *L. indica* Annandale, 1911, believed to be endemic to the Western Ghats (Annandale 1911; Agharkar 1913; Ramakrishna et al. 1950; Birsal 1994), *L. nepalensis* (Dumont, 1976) and *L. biharensis* (Ahmad et al., 1987), are both from northern India. *Craspedacusta* is a genus with three confirmed species spread across eastern Asia, of which only *C. sowerbii* has been reported from the Indian sub-continent. The first formal record of *L. indica* was from the Koyna and Venna rivers of the Krishna Basin (Annandale 1911), where medusae were reported annually during summer months when flowing rivers are reduced to pools. Other locations where *L. indica* are reported include Pampadampara tanks and Periyar Lake in Travancore (Darling 1935; Jones 1951), Sharavathi River, at the bottom of Jog Falls (Ramakrishna et al. 1950), Thunga River (Iyengar & Venkatesh 1955) and the Krishnarajasagar Reservoir on the Cauvery River

Editor: Anonymity requested.

Date of publication: 26 March 2021 (online & print)

Citation: Sreenivasan, N. & J. Barton (2021). Freshwater medusae *Limnocnida indica* Annandale, 1911 in the Cauvery Wildlife Sanctuary, Dubare Reserve Forest and Shivanasamudram in Karnataka, India, with a commentary note on the exotic *Craspedacusta sowerbii* Lankester, 1880. *Journal of Threatened Taxa* 13(3): 18035–18038. https://doi.org/10.11609/jott.6609.13.3.18035-18038

Funding: None.

Competing interests: The authors declare no competing interests.

(Krishnamurthy 1951). Recently, *Limnocnida* received media attention as a chance discovery from a lake in Kodaikanal (Saravanan et al. 2018).

In the Cauvery Basin, there are only two published reports of *L. indica*. The first report is from Krishnarajasagar Reservoir near Sagarkatte Village on the 27 April 1948 (Krashnamurthy 1951). The second report is from the Hemavathi Reservoir between February and March 2002–2004 (Manna et al. 2005). There is a growing concern among nature enthusiasts that freshwater medusae in the Cauvery River are invasive species. Oualid et al. (2019) highlight the negative implications of a similar global trend of exponentially increasing number of morphology-based reports of invasive species. In the Cauvery, this misidentification is largely due to the lesser-known status of *L. indica* that are easily mistaken for *C. sowerbii*, a better-known cosmopolitan species (Jankowski 2001; Fritz et al. 2007; Oualid et al. 2019) originating from the Yangzte River in China (Kramp 1950). *C. sowerbii* are considered invasive at many locations (Oualid et al. 2019) including India (Riyas & Kumar 2017). The invasiveness and impact of freshwater medusae on ecosystems are still not well known (Riyas & Kumar 2017), however, since they feed on zooplankton (Spadinger & Maier 1999; Jankowski 2000; Jankowski & Ratte 2001; Stefani et al. 2010) and occasionally on small fish and their eggs (Jankowski et al. 2007), their potential to become invasive in large numbers cannot be ruled out (Dumont 1994; Jankowski et al. 2005). Fortunately, there are only three reports of the *C. sowerbii* in India and all three of them were found in artificial structures. Joshi & Tanapi (1965) made the first report from an experimental tank at the Poona University on 18 August 1962. Sarkar & Mude (2010) reported *C. sowerbii* from an abandoned rock quarry at Kunnanpara near Thiruvananthapuram, Kerala. Riyas & Kumar (2017) recently reported *C. sowerbii* from an artificial pond at Chemeenchal, Vallakunnu, Thrissur district, Kerala in November 2016. There is one additional report from the Kodagu District (Sarkar & Mude 2010) in which *C. sowerbii* is reported from the Cauvery River but no photographs are available and it may be possible that they were misidentified.

Here, we report the occurrence of *L. indica* medusae from three locations in the Cauvery River in Karnataka: 1) Doddamakkali, in the Cauvery Wildlife Sanctuary (12.308N, 77.217E), 2) Dubare elephant camp, Dubare Reserve Forest in Kodagu District (12.371N, 75.905E), and 3) Malligemaradahalla Lake, near Shivanasamudram (12.301N, 77.144E) where recreational anglers from the Wildlife Association of South India (NGO) report a sighting of freshwater medusae on 13 April 2007. In Doddamakkali, *L. indica* were found in almost stagnant waters in the recesses of large rock formations on the sides of the Cauvery River; in pools fed from rainwater or formed by the receding river itself. In Dubare, the medusae were observed in very still waters of an inlet off the main river. In Malligemaradahalla Lake the medusae were noticed along the bank close to an inlet canal. At all locations, the water was still, there was no sediment, the bed was rocky and the surface of the water was shaded. Medusae were observed at a depth of half a meter to one meter. They were active, usually swimming downward at shallow angles and upward more vertically. Sometimes 20–30 individuals could be seen in one square meter area but they did not seem to gather in any particular pattern. The medusae moved smoothly in the typical style of a jellyfish and did not react noticeably to any disturbance by the observer or equipment. All observations were made during the afternoon and photographs were taken using a Nikon D800 with a Tokina 10-17mm wide angle, using natural light in an Aquatica underwater housing.

Both species *L. indica* and *C. sowerbii* are closely related in morphology but can be distinguished in the field by the arrangement of the gonads on the manubrium (Darling 1935; Ahmad et al. 1987). *C. sowerbii* have large 'pouch-like' gametogenic tissue that hang from the radial canals (Jankowski 2001; Oualid et al. 2019) and in *L. indica* the gonads are arranged in a ring around the stomach (Ahmad et al. 1987) (See Image 1). Further, Joshi & Tonapi (1965) suggest that *C. sowerbii* occur in August in India while the medusae of *L. indica* are reported in pre-monsoon between February and May (Agharkar 1913; Rao 1931; Joshi & Tonapi 1965; Birsal 1994). This temporal variation in the occurrence of medusae can also be considered as a good distinguishing character between the two genera. This first report of *L. indica* from the Cauvery Wildlife Sanctuary (an IUCN category IV protected area) in addition to several other endemic and endangered fish species (Sreenivasan et al. 2021) such as the Humpback Mahseer *Tor remadevii*, Silund Catfish *Silonia childreni*, and Nilgiri Mystus *Hemibagrus punctatus* highlights the importance of approximately 80 km of river habitat that lies between Shivanasamudram Falls and Hoganekal Falls. This stretch of the river is especially important from a conservation perspective as it is the last 'free-flowing' river stretch along the otherwise heavily utilized Cauvery River.

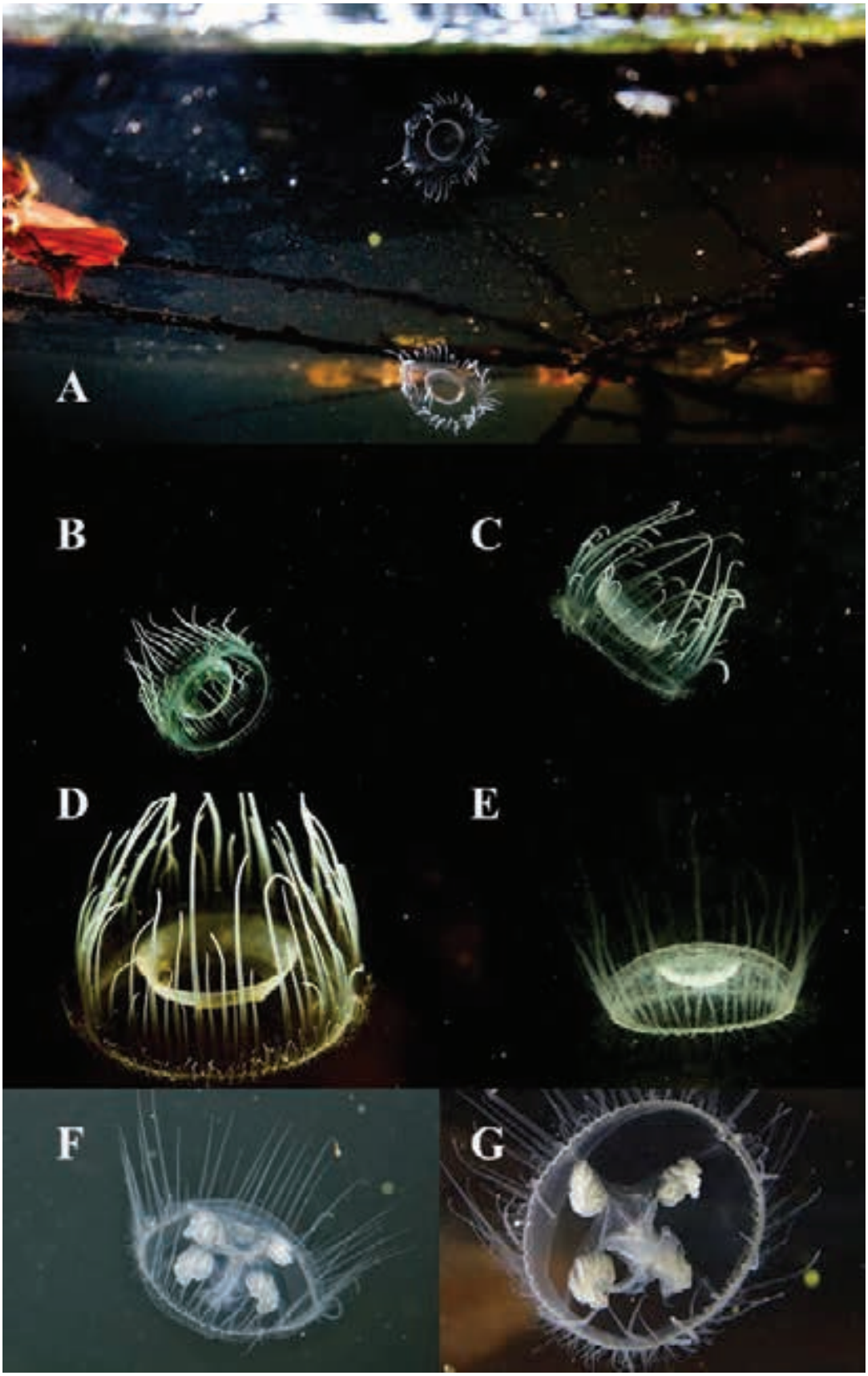

Image 1 . (A) Medusae of *Limnocnida indica* in their natural habitat at Dubare Reserve Forest, Kodagu District, (B–E) various perspectives of the medusa of *L. indica* photographed from the Cauvery Wildlife Sanctuary. Gametogenic tissue is visible as a (inner) ring which can be used to distinguish the medusae from that of *Craspedacusta sowerbii* (F–G) which have 'pouch-like' gonads arranged on radial canals. © (A–E) Joshua Batron & (F–G) Franz Brümmer.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18039–18041
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.5938.13.3.18039-18041
#5938 | Received 01 April 2020 | Final received 05 January 2021 | Finally accepted 28 February 2021
PLATINUM OPEN ACCESS

NOTE

Actinor radians (Moore, 1878) (Hesperiidae: Hesperiinae: Aeromachini): addition to the butterfly fauna of Haryana, India

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Actinor Watson, 1893 is a monotypic genus represented by *Actinor radians* (Moore, 1878). The species is distributed in western Himalaya (from Kumaon in India to Chitral in Pakistan) (Evans 1932). Moore (1878) described the species from Dharmasala, Himachal Pradesh under the genus *Halpe* Moore, 1878. Subsequently, the species was reported from Mandi, Himachal Pradesh (Elwes & Edwards 1897), Doon Valley (Mackinnon & de Nicéville 1898), Utzen Valley (Leslie & Evans 1903; Evans 1910), and Chitral in Pakistan (Evans 1912). Singh & Bhandari (2003) included the species in the list of Dehra-Dun valley following Mackinnon & de Nicéville (1898). Kumar (2010) recorded the species from Jharipani and Bhatta Phal Village of Mussoorie based on the collection of Zoological Survey of India (ZSI) in 2003 and 2002 respectively; however, the authors did not provide detailed information on the record of the species. Interestingly, this record has not been cited in the list of butterflies from Garhwal, Uttarakhand by Singh & Sondhi (2016), though Sondhi & Kunte (2018) do mention the ZSI records. Recently, Tshikolovets & Pagès (2016) reported the species from Kohala, Muzzafarabad, Pakistan at an elevation range of 700–800 m. Currently, this scarce species is known from Chitral to Uttarakhand through Kashmir, Himachal Pradesh (Kangra, Kullu, Simla) and north Punjab (Chandigarh) within an elevation range of 600–2,400 m (van Gasse 2017).

In one of our visits to Kalesar National Park (KNP), Haryana (Figure 1), we encountered a single individual of *A. radians* (Image 1) at 21.04h on 09 August 2019. We photographed the species and later identified with the help of the description provided by Moore (1878), Watson (1893), Elwes & Edwards (1897), Sondhi & Kunte (2018), and the photograph available in www.ifoundbutterflies.org (Anonymous 2020). The species recorded from KNP is confirmed as *A. radians* by the combination of the following characters: discal band of the forewing is irregular and continuous, lower angle of the spots of the discal band continued outward along the veins; three apical spots on forewing shifted in from the discal band; the post discal band of the hindwing continuous from the vein 1b to 6, the medial band from the vein 1b passes across end cell upto vein 8, top most spot between vein 7 and 8 of the hindwing shifted out from the medial band; a basal spot present between upper border of the cell and vein 8 on the hindwing; margin of the hindwing yellow; vein 2 of the hindwing nearer to the end cell than the base of the wing; vein 3

Editor: Sanjay Sondhi, Titli Trust, Dehradun, India.

Date of publication: 26 March 2021 (online & print)

Citation: Boruah, B., R. Chahal & A. Das (2021). *Actinor radians* (Moore, 1878) (Hesperiidae: Hesperiinae: Aeromachini): addition to the butterfly fauna of Haryana, India. *Journal of Threatened Taxa* 13(3): 18039–18041. https://doi.org/10.11609/jott.5938.13.3.18039-18041

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are thankful to Haryana Forest Department and Director, Wildlife Institute of India for giving us permission to visit Kalesar National Park. We thank the forest staff for their help during the visit and Amir Lone, Pallavi Ghaskadbi, & Kumudani Bala Gautam for helping in this work.

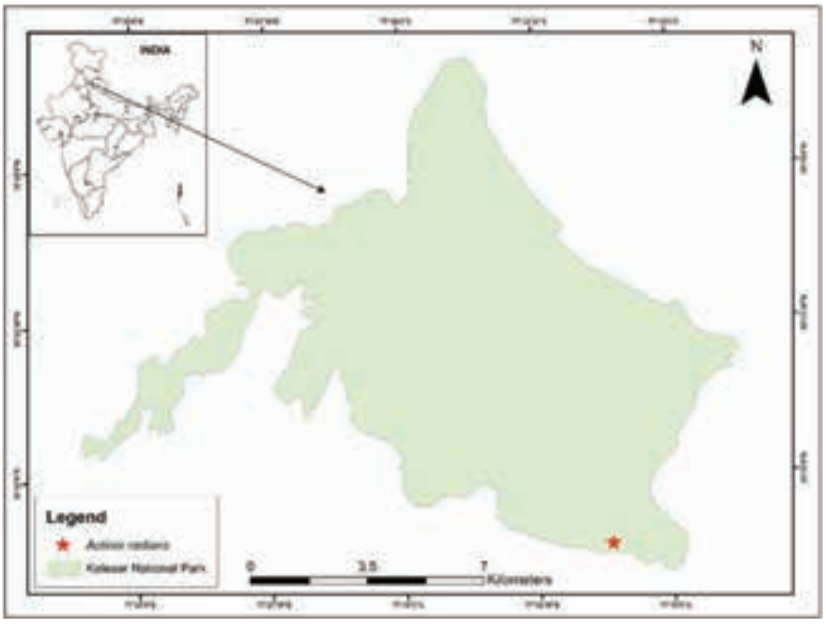

Figure 1. Kalesar National Park and recorded locality of *Actinor radians* (Moore, 1878).

Image 1. *Actinor radians* (Moore, 1878) on grass blade of *Saccharum bengalense*.

of the hindwing originates immediately before the end cell; vein 5 of the hindwing distinctly traceable; vein 7 of the hindwing is close to end cell and originating at an acute angle; all the veins and discal bands pale yellow; antennae with slender club and sharp hook at the tip.

We recorded the species near a perennial stream (30.314˚N & 77.564˚E) at an elevation of 345m, approximately 70m downstream of Chand Sot dam in Tajewala, southeastern part of KNP. The individual was observed perching on a grass blade of *Saccharum bengalense* at a height of one meter above ground (Image 1). The bank of the stream at the recorded site is mostly covered by *Saccharum bengalense*, *Parthenium hysterophorus* along with other shrubs and some broad leaf trees, bamboo at the edge (Image 2).

Kalesar National Park is located in the eastern part of Yamunanagar, Haryana, in the Shivalik range, south of Himalaya. The river Yamuna described the eastern boundary of the park. The park is primarily dominated by Sal and Khair forest with scattered grassland.

The present record of *Actinor radians* from KNP is the lowest distribution limit (elevation 345m). The present

Image 2. Habitat at the location where *Actinor radians* was sighted.

record extend its range ca. 40km from nearest known location (Dehradun Valley) as well as first report of the species from the state of Haryana. The species was not reported in earlier studies by Sethy & Ray (2010) and Ranade (2017) from KNP. With the present record the number of butterflies of Kalesar National Park increases to 40. This report highlights the paucity of knowledge on faunal diversity especially lower taxa in the region as well as importance of the last remaining forest at the extreme end of the Terai Arc landscape.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18042–18044
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6348.13.3.18042-18044
#6348 | Received 30 June 2020 | Final received 01 January 2021 | Finally accepted 11 March 2021
PLATINUM OPEN ACCESS
NOTE

Rediscovery of the rare Desert Grizzled Skipper *Spialia doris evanida* Butler, 1880 (Hesperiidae: Pyrginae) from the Thar Desert, Rajasthan, India

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The Desert Grizzled Skipper *Spialia doris*, also known as the Aden Skipper, prefers an arid and rocky environment and was first described from 'Tajora' (Tadjoura, Djibouti) by Walker (1870). It is distributed in northern Africa, the Arabian peninsula, Turkmenistan, Iraq, Iran, Pakistan, and India (Tshikolovets & Pages 2016; Veronik et al. 2018). The species is further identified at four subspecies levels (Cock 2016): 1) *Spialia d. doris* (Walker, 1870); 2) *S. d. amenophis* (Reverdin, 1914); 3) *S. d. daphne* (Evans, 1949), and 4) *S. d. evanida* (Butler, 1880) (Evans 1949; de Jong 1978; Larsen 2005). Although globally listed as 'Least Concern' on the IUCN Red List (van Swaay et al. 2014), it is rare, sporadically distributed and has not been seen in the past 67 years (see below) in India. In this paper we report the rediscovery of this species from the Thar Desert, Rajasthan (western India) with a note about its habitat and collate all available information to provide a complete database for *S. d. evianida*.

On 7 October 2016, around 17.55h, SSM spotted and photographed a butterfly sitting on top of an inflorescence of *Dactyloctenum aristatum* grass (Image 1) about 30cm high, near a power sub-station Lodurva, Jaisalmer (26.942^{0}N & 70.875^{0}E), Rajasthan. The weather was dull and pleasant with ambient temperature of about 30°C when the butterfly was spotted. As the butterfly was photographed just prior to sunset, the individual may have been there to stay for the night and was sitting at an optimal height above the ground that may have helped it avoid ground predators such as lizards, skink, and snakes. Later it was identified as *Spialia doris evanida* with the help of the literature (Evans 1932, 1949; de Jong 1978; Roberts 2001; Tshikolovets & Pages 2016), and the images available on the world wide web. The area where the individual was spotted had shrub and bushy, sparse grassland habitat. The main plant species were *Acacia* sp., *Calotropis procera*, *Laptodania pyrotechnica*, *Euphorbia* sp., *Zizyphus* sp., *Crotalaria burhia, Heliotropium bacciferum*, and *Convolvulus* sp. (Image 2). As it was the monsoon season, there was a temporary water channel at about 100m distance with a few puddles in its bed.

The *S. doris* is different from *S. galba* (the only other species of this genus known in India), having a smaller size with a forewing length of 9–11 mm (vs 11–13 mm

Editor: Anonymity requested.

Date of publication: 26 March 2021 (online & print)

Citation: Meena, S.S., A. Tripathi, V.K. Koli & M.A. Awan (2021). Rediscovery of the rare Desert Grizzled Skipper *Spialia doris evanida* Butler, 1880 (Hesperiidae: Pyrginae) from the Thar Desert, Rajasthan, India. *Journal of Threatened Taxa* 13(3): 18042–18044. https://doi.org/10.11609/jott.6348.13.3.18042-18044

Funding: The work is not funded by any funding agency.

Competing interests: The authors declare no competing interests.

Acknowledgements: We thank to Dr. Dheeren Panwar for plant identification.

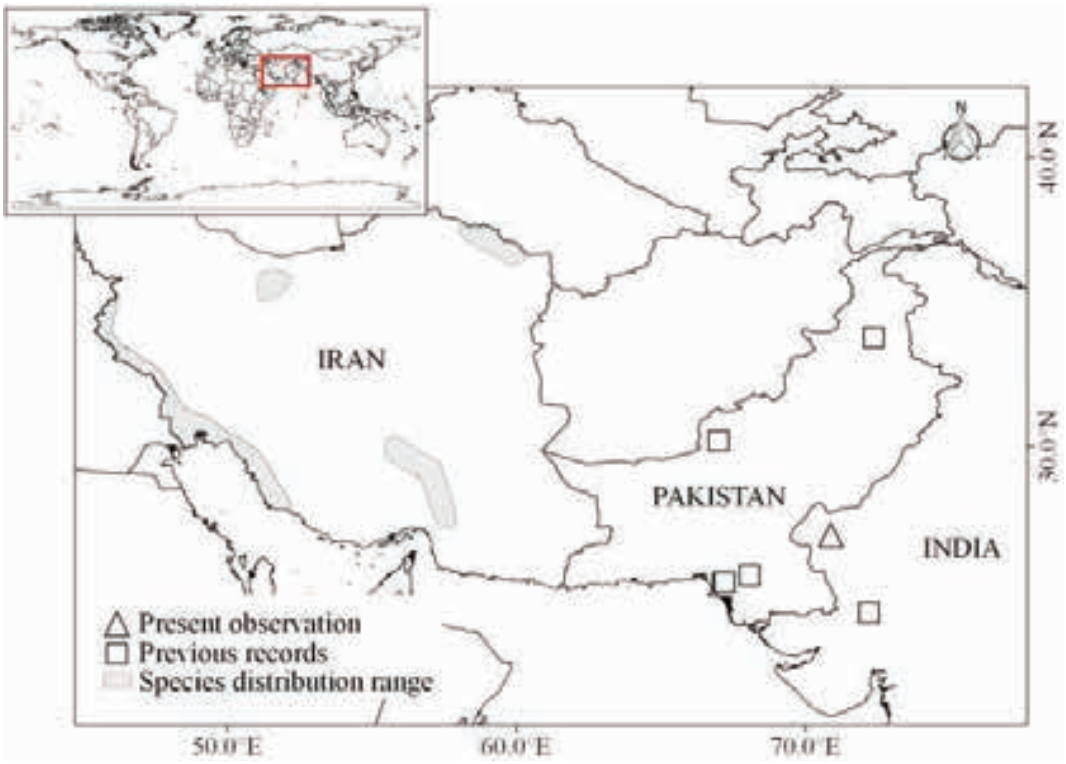

Figure 1. Eastern distribution of the Desert Grizzled Skipper *Spialia doris evanida* Butler with present record (△) from the Thar Desert, western India.

in *S. galba*), under hindwing ground colour being paler greyish-brown with a faint yellow tint (vs darker brown in *S. galba*) and bands on under hindwing being broken into spots (vs prominent basal and discal bands being present in *S. galba*) (Tshikolovets & Pages 2016) (Image 1). The *S. galba* is seen in grasslands as well as in forests up to 1,300m in the Himalaya and 2,700 m in the hills of southern India, but which is found absent in arid and wet dense habitats (Kehimkar 2008). Its identified larval food plants are *Hibiscus* sp., *Sida rhombifolia* (Malvaceae), and *Waltheria indica* (Sterculiaceae), while plants of Malvaceae and Convolvulaceae (include *Corchorus* sp., *Convolvulus* sp.) preferred by *S. doris* (Pittaway 1980; Benyamini 1984; Pittaway 1985; Pittaway et al. 2006; Cock 2016; Norfolk & Dathe 2019). Robert (2001) identified Rosaceae family members, particularly *Potentilla supina,* and possibly *Neurada procumbens* as species of larval food plants particularly to *S. d. evanidus.*

The subspecies of *S. doris* found in Iran, Pakistan and India are known as *S. d. evanida* (Butler 1880). It was first discovered (and described as a new species) from Sao, near Hubb River, Balochistan, Pakistan (type specimen was collected on 20 November, 1879 and figured in Tshikolovets & Pages (2016)). This subspecies was later collected from Deesa, Rajputana (currently located in the state of Gujarat, India), and Campbellpur, Punjab (Pakistan) (Evans 1949). In Iran, this taxon has been recorded extensively from Tehran, Alborz, Khorasan, Kerman provinces and southern drier provinces from Ilam to Busher (Tshikolovets et al. 2014; Naderi 2019) (Figure 1). Evans (1932) retained its specific status (*Spialia evanidus*) and named it also the Sindh Skipper. Evans (1949) then synonymized *evanida* with the nominate subspecies. We follow de Jong (1978), Tshikolovets et al. (2014), Tshikolovets & Pages (2016), Naderi (2019), Van

Image 2. Typical habitat overview where the Desert Grizzled Skipper *Spialia doris evanida* was spotted.

Image 1. A—The Desert Grizzled Skipper *Spialia doris evanida* photographed at Jaisalmer, Rajasthan on 7 October 2016 | B—Indian Skipper *S. galba* for comparison.

Gasse (2018), and Anonymous (2020a) and accept *Spialia doris evanida* (Butler 1880) as a valid subspecies.

The *S. d. evanida* is recently rediscovered from Pakistan (Anonymous 2020b). As, only a male of the species was for the first and last time collected from India by Evans (1949), the present finding is an important record of this rare species and after 67 years, it is a rediscovery. Further, more attention of researchers and detailed survey in the Thar Desert may help to track this species and its natural history in future.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18045–18049
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6517.13.3.18045-18049
#6517 | Received 04 August 2020 | Final received 12 October 2020 | Finally accepted 06 March 2021
PLATINUM OPEN ACCESS

NOTE

Habitat association and hybridization in woodbrowns (*Lethe nicetas*, *L. sidonis*, & *L. dakwania*) (Lepidoptera: Nymphalidae: Satyrinae) in Kedarnath Musk Deer Reserve, western Himalaya

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The 'woodbrown' group of the genus *Lethe* (Nymphalidae: Satyrinae: Satyrini: Lethina) occurs as five species in western Himalaya. The most common and widely occurring species is the Common Woodbrown *Lethe sidonis* (Hewitson, 1863) (45–60 mm) which occurs from Chamba, Himachal Pradesh up to Arunachal Pradesh and Shan states in Myanmar from April to October at 975–3,352 m. Its larva is known to feed on Hill Bamboo *Arundinaria falcata* Nees. A similar looking and lesser known species is the White-wedged Woodbrown or the Garhwal Woodbrown *Lethe dakwania* Tytler, 1939 found in Garhwal. Specimens of both the sexes of this little known species were collected by H.C. Tytler during August 1914 from Dakwani, eastern Garhwal (2,700m) in northern India. Another species that occurs along with these two is the Yellow Woodbrown *Lethe nicetas* (Hewitson, 1863) (48–55 mm) which is distributed from Kangra in Himachal Pradesh up to Arunachal Pradesh in the Himalaya, northeastern India and northeastern part of Myanmar. It occurs at 1,700–2,620 m with a flight period from May to November and is 'not rare' in its distribution range. This species is more common in June–October (900–1,800 m) in Kumaon region of the western Himalaya. The fourth species is the Himalayan Barred Woodbrown *Lethe maitrya maitrya* de Nicéville, [1881] (45–55 mm) which occurs from Kullu in Himachal Pradesh up to Sikkim and Bhutan where it is 'not rare' at 2,500–3,800 m in April–October. The fifth species is the Scarce Woodbrown *Lethe siderea siderea* Marshall, 1881 (48–55mm) that is distributed from Garhwal to northeastern India & northern Burma where it is 'rare' and occurs between 2,000–2,620 m from May–October (Mackinnon & Nicéville 1899; Hannyngton 1910; Evans 1932; Wynter-Blyth 1957; Smith 1989, 2006; Varshney & Smetacek 2015; Singh & Sondhi 2016; Kehimkar 2016; Gasse 2013).

During the course of several surveys carried out in Kedarnath Musk Deer Reserve (KMDR) in 2006–2019, observations were recorded and random samples collected of the *Lethe* genus of the group 'Woodbrown' at various locations representing different altitudes and vegetation types. Analysis of photographs, specimens and male genitalia revealed the occurrence of only three species of woodbrowns in KMDR out of five known from western Himalaya. These were: *L. sidonis*, *L. dakwania*, & *L. nicetas* (Image 1, 2, 3, 5, 6 & 7). The species have been earlier reported from Mandal and Kanchula Kharak areas inside KMDR as "common" (Singh & Sondhi 2016).

Editor: Anonymity requested.

Date of publication: 26 March 2021 (online & print)

Citation: Singh, A.P. & T. Singh (2021). Habitat association and hybridization in woodbrowns (*Lethe nicetas*, *L. sidonis*, & *L. dakwania*) (Lepidoptera: Nymphalidae: Satyrinae) in Kedarnath Musk Deer Reserve, western Himalaya. *Journal of Threatened Taxa* 13(3): 18045–18049. https://doi.org/10.11609/jott.6517.13.3.18045-18049

Funding: Indian Council of Forestry Research & Education (ICFRE).

Competing interests: The authors declare no competing interests.

Acknowledgements: The current findings are part of a ICFRE research project entitled "Butterflies associated with different forest types/sub-types in Uttarakhand (FRI-627/FED-44; 2017-2021)" being carried out at the Forest Research Institute, Dehradun.

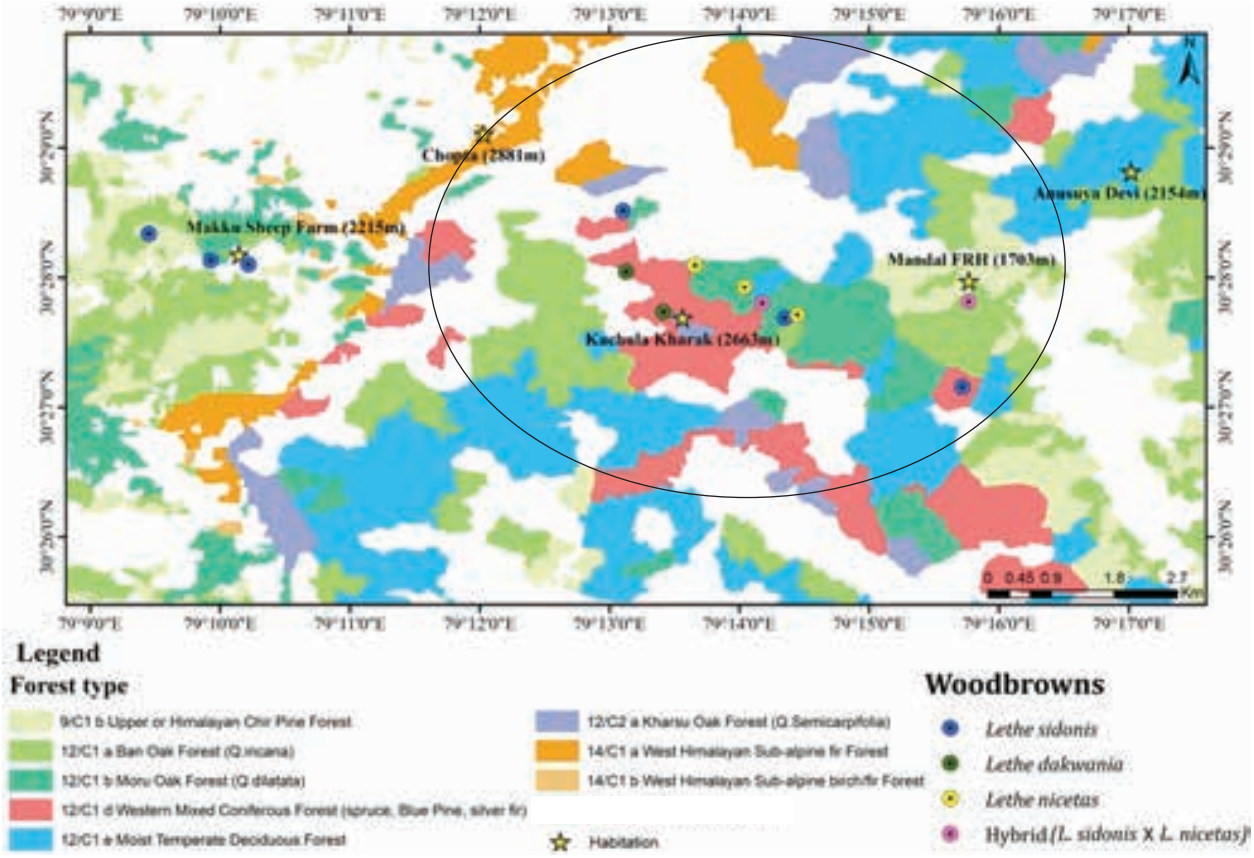

Figure 1. False colour composite satellite imagery showing the forest sub-types associated with the three species of Woodbrowns (*Lethe nicetas*, *L. sidonis*, & *L. dakhwania*) in Kedarnath Musk Deer Reserve, western Himalaya along with prominent locations inside the forest habitats (star markings).

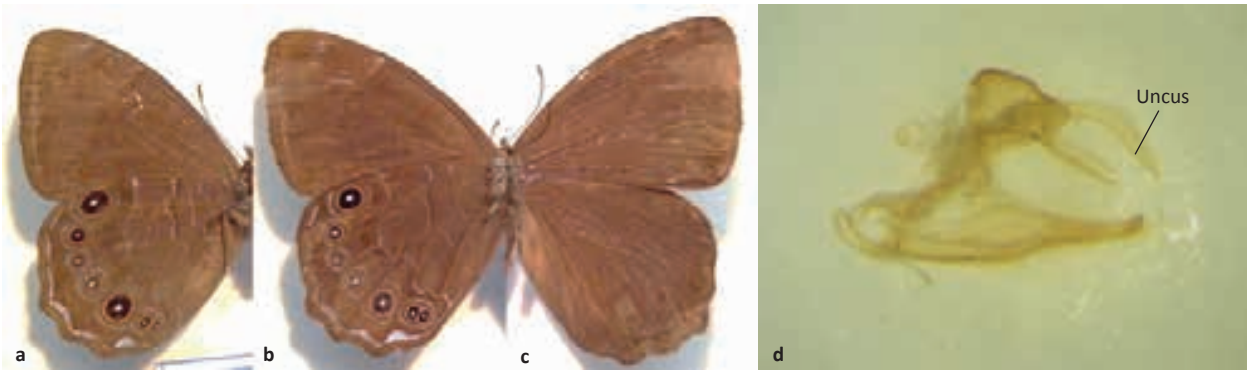

Image 1 a–c. Common Woodbrown *Lethe sidonis* (Hewitson, 1863) collected on 26.ix.2006 from Kedarnath Musk Deer Reserve, Garhwal: a & b—underside | c—upperside | d—male genitalia. © Arun Pratap Singh

Upon examination, these species showed distinct male genitalia. In *L. sidonis*, the uncus, as seen from the side is distinctly raised, and higher and thicker in the middle, and then sharply bent downwards (Image 1 a–c). In *L. dakwania* the uncus is evenly curved and not thicker and raised in the middle, or suddenly bent downwards (Image 2 a–c) (Tytler 1939). In *L. nicetas* (Image 3 a–c) the uncus is bent sharply downwards in the beginning without being thicker or raised in the middle. While in *L. maitrya* (specimen collected from Mussoorie, Garhwal) the uncus is not bent at all but straight and held horizontally in front (Image 4 a–b). Two specimens collected from KMDR seemed morphologically quite similar to *L. nicetas* but were distinct as they had yellow markings on the under

Image 2 a–c. White-wedged Woodbrown/Garhwal Woodbrown *Lethe dakwania* Tytler, 1939 collected on 28.vii.2006 from Kedarnath Musk Deer Reserve, Garhwal: a & b—underside | c—upperside | d—male genitalia. © Arun Pratap Singh

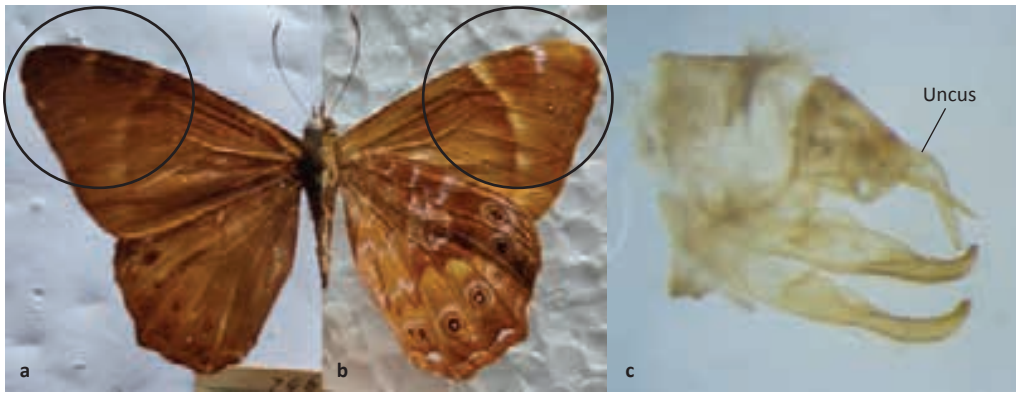

Image 3 a–c. Yellow Woodbrown *Lethe nicetas* (Hewitson, 1863) collected from 24.x.2017 from Kedarnath Musk Deer Reserve, Garhwal: a—underside | b—upperside | c—male genitalia. © Arun Pratap Singh

Image 4 a–b. Himalayan Barred Woodbrown *Lethe maitrya maitrya* de Nicéville [1881] collected from Mussoorie, Garhwal along with its male genitalia: a—underside | b—upperside | c—male genitalia. © Arun Pratap Singh

and upper forewing and under hindwing being 'more extensive' than in *L. nicetas* (Image 8 & circled portions of upper forewings- Image 3 & 9). These specimens were dissected for examining their genitalia but did not reveal any genital organ and were thus classified as hybrids. These specimens were collected during 2006 and then again during 2017, which suggests that the phenomenon of hybridization in an ongoing process in this part of KMDR.

Examination of the altitudinal distributional and forest type association (Figure 1 & Table 1) of these three species in the study area revealed that *L. nicetas* is associated with 12/C1b Moru oak forest (Champion & Seth 1968) and mainly occurs in abundance at 2,260–2,402 m. On the other hand *L. dakwania* occurred at a much higher elevation at 2,729–2,765 m and showed association with

Image 5. a–c—Common Woodbrown *Lethe sidonis* (Hewitson, 1863) at Kedarnath Musk Deer Reserve, Garhwal. © Arun Pratap Singh

Image 6. White-wedged Woodbrown/Garhwal Woodbrown *Lethe dakwania* Tytler, 1939 at Kedarnath Musk Deer Reserve, Garhwal.

Image 7 a–c—Yellow Woodbrown *Lethe nicetas* (Hewitson, 1863) individuals recorded on 24.x.2017 in Kedarnath Musk Deer Reserve, Garhwal. © Arun Pratap Singh

mainly 12/C1d western mixed coniferous forest. While *L. sidonis* had a much wider altitudinal distribution range at 1,700–2,600 m and occurred in at least three forest types: 12/C1a Ban Oak forest, 12/C1b Moru Oak forest, and also 12/C1d western mixed coniferous forest, thus sharing common forest-type habitat with both *nicetas* and *dakwania* in KMDR, therefore having greater chances of hybridization with *L. nicetas*. The hybrids collected (Image 8 & 9) are most likely to be between *nicetas* and *sidonis*. The current findings call for more research into the matter.

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Image 8 a&b. *Lethe* hybrid (*nicetas* x *sidonis*) individuals: a—photographed on 26.ix.2006 | b—photographed on 24.x.2017 in Kedarnath Musk Deer Reserve, Garhwal. © Arun Pratap Singh

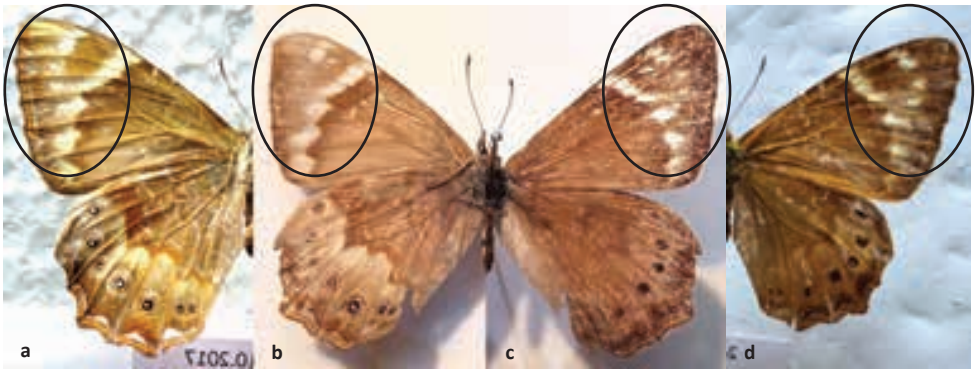

Image 9. *Lethe* hybrid (*nicetas* x *sidonis*) individuals collected on 24.x.2017 (a&d) and 26.ix.2006 (b&c) from Kedarnath Musk Deer Reserve, Garhwal: a,b—upperside | c,d—underside. © Arun Pratap Singh

Table 1. Plant species* (trees & bamboos) composition of the three different forest sub-types (Champion & Seth 1968) associated with the three species of Woodbrowns (*Lethe nicetas*, *L. sidonis*, & *L. dakhwania*) in Kedarnath Musk Deer Reserve, western Himalaya.

Associates	12/C1a Ban Oak forest (*Quercus leucotrichophora* A.Camus)	12/C1b Moru Oak forest (*Quercus floribunda* Lindl. ex A.Camus)	12/C1d western mixed coniferous forest (*Abies pindrow* (Royle ex D.Don) Royle, *Pinus wallichiana* A.B.Jacks)
a) Trees b) Dwarf Bamboos	*a) Acer caesium* Wall. ex Brandis *Acer oblongum* Wall. ex DC. *Aesculus indica* (Wall. ex Cambess.) Hook. *Alnus nepalensis* D.Don *Betula alnoides* Buch.-Ham. ex D.Don *Boehmeria rugulosa* Wedd. *Cinnamomum tamala* (Buch.Ham.) T. Nees & C.H.Eberm *Cornus capitata* Wall. ex Roxb *Euonymus lacerus* Buch.-Ham. *Ficus auriculata* Lour. *Fraxinus micrantha* Lingelsh. *Inula cuspidate* (Wall. ex DC.) C.B.Clarke *Lindera pulcherrima* (Nees) Benth. *Litsea umbrosa* (Nees) Nees *Lyonia ovalifolia* (Wall.) Drude, *Machilus odratissima* Nees *Machilus duthiei* King ex J.D.Hooker *Marsine semiserata* Wallich *Pryrus pashia* Linnaeus *Rhododendron arboretum* Sm. *Sarcococca saligna* (D.Don) Müll.Arg. *Xanthoxylum armatum* DC. b) *Sinarundinaria falcata* (Nees) C.S.Chao & Renvoize	a). *Acer caesium* Wall. ex Brandis *Acer sterculiaceum* Wall. *Aesculus indica* (Wall. ex Cambess.) Hook. *Betula alnoides* Buch.-Ham. ex D.Don *Carpinus viminea* Wall. ex Lindl. *Eurya acuminata* DC. *Fraxinus micrantha* Lingelsh. *Ilex dipyrena* Wall. *Machilus duthiei* King ex J.D.Hooker *Rhamnus purpureus* Edgew. *Rhododendron arboreum* Sm. *Symplocos chinensis* (Lour.) Druce b). *Sinarundinaria falcata* (Nees) C.S.Chao & Renvoize	a). *Quercus semecarpifolia* Sm. *Acer caesium* Wall. ex Brandis *Acer cappadocicum* Gled. *Euonymus lacerus* Buch.-Ham *Rhdodendron aboreum* Sm. *Rhamnus purpureus* Edgew. *Smilax vaginata* Decne. *Taxus wallichiana* Zucc. *Juniperus indica* Bertol. b). *Thalmnocalamus falconeri* Hook.f. ex Munro *Yushania anceps* (Mitford) W.C.Lin

Identification of plant species based in the field with the help of field guide (Rai et al. 2017) and herbarium specimens collected during field surveys by the authors and identified at FRI, Dehradun Herbarium with the help of plant taxonomists.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18050–18053
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.6709.13.3.18050-18053
#6709 | Received 13 September 2020 | Final received 16 November 2020 | Finally accepted 17 March 2021
PLATINUM OPEN ACCESS

NOTE

Begonia flaviflora Hara (Begoniaceae): a new record to the flora of Bhutan

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The genus *Begonia* L. (Begoniaceae) is one of the largest genera of angiosperm in the world, estimated to comprise up to approximately 2,500 species (Tian et al. 2018), of which about 1991 are currently accepted species (Hughes et al. 2015), currently divided into 70 sections and distributed mostly in the tropical and subtropical zones in the world (Doorenbos et al. 1998; Moonlight et al. 2018). In Asia, around 959 species in 19 sections have been recorded with maximum occurances in southeastern Asia (Shui et al. 2002; Moonlight et al. 2018). *Begonia* sect. Platycentrum (Klotzsch) A. DC. is the largest section with 16 species in northeastern India (Camfield & Hughes 2018). Grierson (1991) described 20 species of *Begonias* in the Flora of Bhutan, of which only 13 species are recorded from Bhutan. No further study has been conducted on the genus in Bhutan since Grierson (1991) and the occurrence of remaning seven species including *B. flaviflora* are unknown.

During recent botanical exploration in Zhemgang District in August 2020, specimens of an interesting *Begonia* species were collected from the cool broadleaved forest. After substantial study on its morphological characteristics and reviewing the taxonomic literature (Clarke 1879; Hara 1970; Grierson 1991; Tsuechih et al. 1999; Hughes et al. 2015; Camfield & Hughes 2018), and consultation of herbarium specimens available at Global Biodiversity Information Facility (https://www.gbif.org/), and Kew Science (https:/specimens.kew.org/) including the type specimens, it was identified as *B. flaviflora* Hara, a new record to Bhutan. The addition of one species from the current study confirms 14 species of Begonia from Bhutan and more are likely to be found and confirmed with further exploration. Detailed morphological description, phenology, ecology, distribution and notes along with photographs are provided. The voucher specimens are deposited at the National Herbarium (THIM!), National Biodiversity Centre, Thimphu, Bhutan.

***Begonia flaviflora* H. Hara**

J. Jap. Bot. 45: 91. 1970. A.J.C. Grierson In: Grierson & Long. Fl. Bhutan 2(1): 245–246 (1991); K. Tsuechih, C.-I Peng & N.J. Turland. Fl. China 52(1): 174 (1999).

Begonia laciniata subsp. *flaviflora* Irmsch.Mitt. Inst. Allg. Bot. Hamburg. 10: 531. 1939.

Type: India, Sikkim, Darjeeling, 5 July 1969, Hara, *Kurosawa & Ohashi 69218* (holotype: TI n.v.; isotype: BM000839167).

Editor: Anonymity requested. **Date of publication:** 26 March 2021 (online & print)

Citation: Gyeltshen, P., S. Jamtsho, S. Wangchuk & D.B. Subba (2021). *Begonia flaviflora* Hara (Begoniaceae): a new record to the flora of Bhutan. *Journal of Threatened Taxa* 13(3): 18050–18053. https://doi.org/10.11609/jott.6709.13.3.18050-18053

Funding: Self funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: Authors would like to express sincere gratitude to the director general of Department of Forest and Park Services, chief forestry officer of Zhemgang Forest Division, and staff for their constant motivation and encouragement.

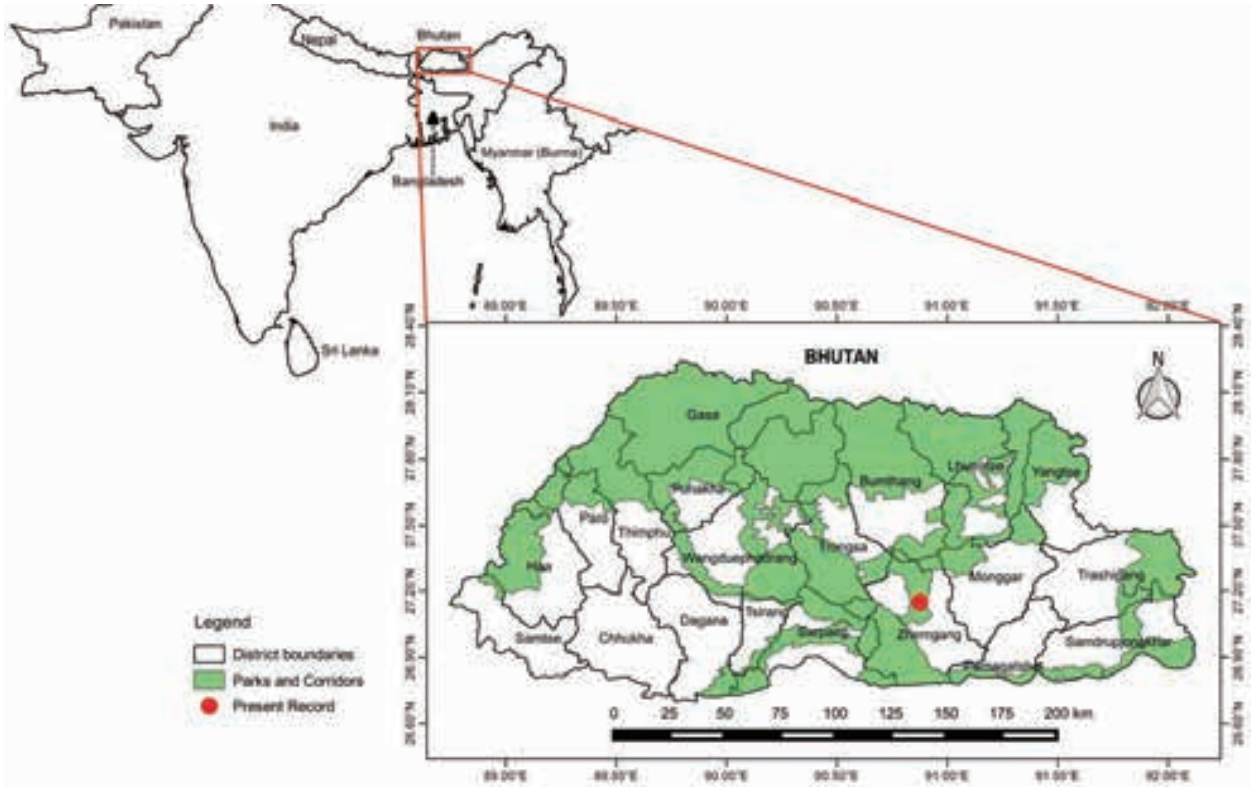

Figure 1. Distribution map of *Begonia flaviflora* Hara in Zhemgang District, Bhutan.

Begonia flaviflora var. *gamblei* (Irmsch.) Golding & Kareg. Phytologia 54: 496. 1984. *Begonia gamblei* (Irmsch.) F.A. Barkley & Golding Sp. Begon. Ed. 2: 44. 1974. *Begonia laciniata* subsp. *gamblei* Irmsch. Mitt. Inst. Allg. Bot. Hamburg. 10: 531. 1939. *Begonia flaviflora* var. *gamblei* H. Hara. Fl. E. Himalaya 1: 215. 1966. *Begonia flaviflora* var. *vivida* Golding & Kareg.Phytologia 54: 496. 1984

Plant monoecious, herbaceous, 30–80 cm tall. Rhizome oblong, 6–12 × 1–3 cm with several offsets giving rise to new shoots, adventitious roots growing from the rhizome. Stem erect, 20–40 cm long, with sparsely brownish pubescent, lowermost internodes 10–22 cm long and 6–7 mm wide, unbranching, 2–4 leaves per stem. Stipule persistent, ovate, 10–15 × 3–5 mm, papery, keeled, apex cuspidate (1–4 mm), margin entire. Leaves alternate; petiole cylindrical, 4–28 cm long, 3–8 mm thick, green, brownish pubescent surface; blade asymmetric, ovate to broadly ovate 10–20 × 8–23 cm, basifixed, apex acute to acuminate or shortly caudate, base deeply cordate, margin shallowly lobed and ciliate, venation palmate-reticulate, 7–8 veined; adaxial surface green or dark green with minute appressed white hairs, hairs less than 0.2mm long; abaxial surface glabrous, sparsely brownish pubescent on veins, green with purplish colour along the veins and towards the margin. Inflorescences cymose, 1–2, terminal or axillary on long stem with 1–2 internodes, 2–4 flowers per peduncle, erect; peduncles cylindrical, 8–15 cm long, 2–3 mm wide, green to red, brownish pubescent. Floral bracts narrowly ovate, 2–3.5 × 1.5–2.5 cm, pinkish, glabrous, margin entire, base and apex truncate, adaxial surface is wrinkled and covered with soft hairs, veins numerous, decduous. Staminate flower: pedicel up to 3cm long, pale red to pale greenish-yellow, brownish pubescent; tepals 4, golden yellow, glabrous, margin entire; outer 2, deltoid, 15–19 × 12–16 mm, cucullate, upper tepal's apex prominently recurved, lower tepal's apex slightly recurved, base truncate, 10–12 veined; inner 2, ovate-elliptic, 12–14 × 7–9 mm, cucullate, apex rounded to sub-acute, base slightly oblique-truncate, 9–11 veined; stamens numerous, 2–3 mm long, filaments free, anther obovate-oblong, golden yellow. Pistillate flower: pedicel up to 3 cm long, pale yellowish-green, light pinkish-green, brownish pubescent; tepals 5, unequal, golden yellow, glabrous, margin entire to slightly wavy; outer 2, ovate, 7–11 × 5–7 mm, concave, apex acute, base truncate, 12–13 veined; inner 3, ovate to ovate-elliptic,

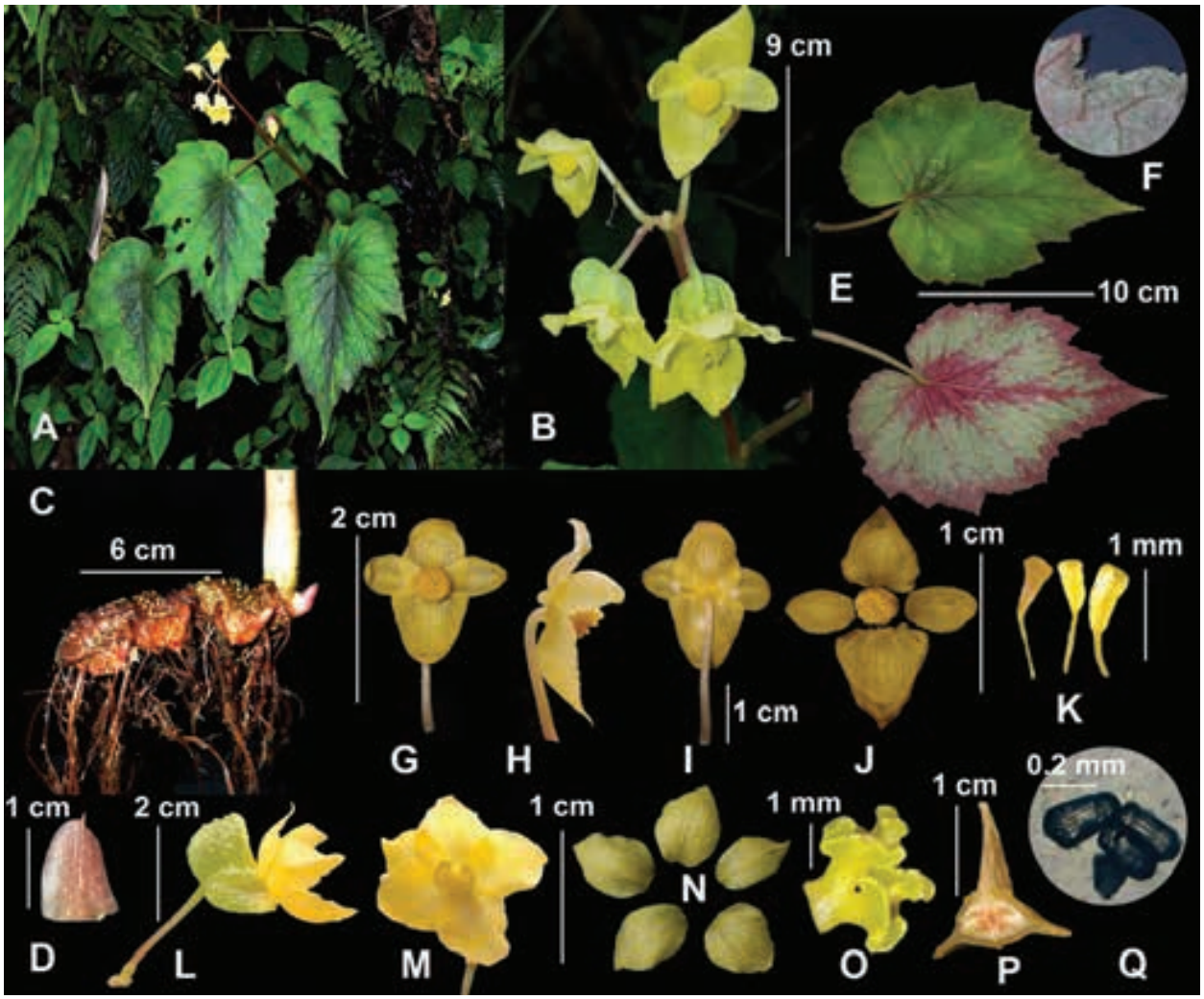

Image 1. ***Begonia flaviflora*** **Hara; A—Habit | B—Inflorescence | C—Underground stem | D—Stipule (abaxial view) | E—Leave | F—Leaf margin | G, H, I—Staminate flower | J—Tepals and androecium of male flower | K—Stamens | L&M—Female flower | N—Tepals of female flower | O—Style and stigma | P—Transverse section of ovary | Q—Seeds. © Phub Gyeltshen.**

17.5–19 × 14–16 cm, concave, apex acute to subacute, base truncate; ovary yellowish-green, glabrous, with three unequal wings, 2 locules, placentation axillary, two branches per locule; styles 2, Y-shaped, 3–3.5 mm long, fused at base,golden yellow; stigma spiraled, papillose all around. Capsule trigonous-globose, 7–11 × 6–8 mm, yellowish-green; longest wing obovoid-oblong, 1.5–1.7 × 1.5–1.7 cm, slightly falcate at apex, crenate, narrow towards base, lateral wings 1.6–2.2 × 0.4–0.6 cm, tuberculate on surface of the ovary including its wings. Seeds numerous, white when young, oblong, c. 0.2–0.3 × c. 0.2 mm.

Specimens examined: THIM15583, 10 August 2019, Shingkhar, Zhemgang, Bhutan, 27.152^{0}N, 90.875^{0}E, 1,914–2,399 m, P. Gyeltshen & S. Sherab 012–013.

Phenology: Flowering and fruiting July to August

Habitat and ecology**:** This species prefers moist soil in shady areas in broadleaved at forest at 1,900–2,400 m elevation. Associated species includes *Pouzolzia hirta* (Blume) Hassk., *Pilea scripta* (Buch.-Ham. ex D.Don) Wedd., *Streptolirion volubile* Edgew., *Swertia bimaculata bimaculata* Hook.f. & Thomson ex C.B.Clarke, *Carpesium nepalense* Less., *Rubus calycinus* Wall., *Dichroa febrifuga* Lour. and *Impatiens pseudolaevigata* Gogoi, B.B.T.Tham & Lidén.

Distribution: India, China, Mayanmar, Nepal, Malaysia, and new to Bhutan.

Notes: The new species is vegetatively similar to *Begonia palmata* but can be distinguished by yellow flower, smaller capsule and wings of the fruit. The key morphological differences between *B. flaviflora* and its closely related taxon *B. palmata* is presented in Table

Table 1. Comparison of key morphological characters of *Begonia flaviflora* and *B. palmata*.

Attributes	*B. flaviflora*	*B. palmata*
Habit	erect, 30–80 cm tall	erect, 45–100 cm tall
Rhizome	10–30 mm wide	5–15 mm wide
Stem	6–7 mm wide, brownish pubescent	5–15 mm wide, sparsely to densely tomentose to villose
Stipule	ovate, 3–5 mm wide	lanceolate , 3–10 mm wide
Petiole	4–28 cm long, brownish pubescent	1.5–19 cm long, densely tomentose to sparsely puberulous
Lamina	ovate to broadly ovate, 10–20 x 8–23 cm, base deeply cordate	narrowly to broadly ovate, 5–20 x 2–20 cm, base truncate, or base cordate to shallowly cordate
Abaxial surface	glabrous, brownish pubescent on veins	pubescent to pilose throughout or denser on veins
Bract	narrowly ovate, 20–35 x 15–25 mm	lanceolate or sub-orbicular or triangular, 6–17 x 3–13 mm
Staminate flower	tepals 4, golden yellow	tepals 4, white to pink
Pistillate flower	tepals 5, unequal, golden yellow	tepals 5, equal, white to pale pink
Style	2 or 3	2
Capsule	trigonous-globose, 7–11 mm long, longest wing obovoid-oblong, 15–17 mm long	oblong-ellipsoid, 7–18 mm long, longest wing triangular to rounded oblong, 9–20 mm long

1 using the descriptions (Grierson 1991; Camfield & Hughes 2018). The current distribution site is located within Biological Corridor–4 of the district with population less than 10 individuals and no threats have been observed in the field.

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Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2021 | 13(3): 18054–18058
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.4801.13.3.18054-18058
#4801 | Received 07 January 2019 | Final received 17 November 2020 | Finally accepted 29 January 2021
PLATINUM OPEN ACCESS
NOTE

Revisiting the taxonomy of *Strobilanthes lawsonii* and *S. pushpangadanii* (Acanthaceae), two endemic taxa of Western Ghats, India

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Strobilanthes Blume (1826), the second largest genus in the family Acanthaceae Juss. (1789), consists of 400 species restricted to the hilly regions of tropical Asia (Wood 1998; Augustine 2018). In India, it is represented by 160–170 species from the mountains of peninsular India and the Himalaya of northeastern and northwestern India. In peninsular India, 65 taxa are recorded so far with many new recent additions (Gamble 1924; Venu 2006; Josekutty et al. 2016, 2017, 2018; Sasidharan et al. 2016; Augustine et al. 2017; Biju et al. 2017; Augustine 2018). Clarke (1885) enumerated 146 species of *Strobilanthes* in the Flora of British India. In southern India and Sri Lanka, the genus is represented by 65 species, of which most are endemics (Carine & Scotland 2002).

EIght years of explorations in the southern region of the Western Ghats has resulted in the documentation and collection of many endemic *Strobilanthes* species. Among them, materials collected from Nelliyampathy forests (CMPR 8707, 9589) and Muthikulam forests (CMPR 9879) of Palakkad District, Kerala did not key out their identity exactly. After detailed taxonomic studies with the perusal of relevant literature (Clarke 1885; Gamble 1924; Santhoshkumar et al. 2002; Venu & Daniel 2003; Carine et al. 2004; Venu 2006) revealed their identity as *S. pushpangadanii* E.S.S. Kumar et al. (2002: 73), *S. gamblei* Carine et al. (2004: 5), and *S. lawsonii* Gamble (1923: 374) respectively.

Since 1923, many subsequent researchers recorded the distribution of *S. lawsonii* from different localities of Kerala in their floristic reports (Ramachandarn & Nair 1980; Sasidharan 2004, 2013). But our herbarium survey revealed that the materials so far identified as *S. lawsonii* are either *S. gamblei* or *S. pushpangadanii*. Hence our present collection is a rediscovery of *S. lawsonii* after Gamble's collection in 1884, after a lapse of 133 years.

Based on the evidence of the live collection of *S. gamblei* and *S. pushpangadanii* from Nelliyampathy forests of Palakkad, we reinstate *S. pushpangadanii* as a distinct species, with the most notable morphological differences from *S. lawsonii* (Table 1) being partially fused corolla lobes, exserted stamens, and glabrous style. The latter species, S. gamblei has been recently reinstated by Pradeep et al. (2020).

Editor: N.P. Balakrishnan, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 March 2021 (online & print)

Citation: Cherian, B., K.M. Prabhukumar, R. Jagadeesan, V.V.N. Kumar & I. Balachandran (2021). Revisiting the taxonomy of *Strobilanthes lawsonii* and *S. pushpangadanii* (Acanthaceae), two endemic taxa of Western Ghats, India. *Journal of Threatened Taxa* 13(3): 18054–18058. https://doi.org/10.11609/jott.4801.13.3.18054-18058

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors express sincere gratitude to authorities of Arya Vaidya Sala, Kottakkal for their support and Tata Trusts, Mumbai for financial assistance. Thanks are also due to Dr. Mark Carine, The Natural History Museum, United Kingdom and Dr. E.S. Santhosh Kumar, JNTBGRI, Thiruvanathapuram for their comment on the identity *S. gamblei* and *S. pushpangadanii* respectively; Dr. Maya C. Nair, Govt. Victoria College, Palakkad, P.M. Binu Prakash, CMPR for their help in the field. Department of Kerala Forest is also thankfully acknowledged for the permission granted to enter the forest.

Strobilanthes lawsonii Gamble Bull. Misc. Inform. Kew 1923: 374. 1923. (Image 1, Figure 1)

Type: Tamil Nadu. Nilgiri Distr., 6000ft., Nov. 1883, *Gamble* 13387 (lectotype: K!)

=*Phlebophyllum lawsonii* (Gamble) Bremek., Verh. Acad. Wet. afd. Natuurk. Sect. 2, 41: 169. 1944.

Type: Same as *S. lawsonii.*

Erect shrubs. Stem quadrangular with dense tawny coloured short simple hairs; young branches are similar to that of its main axis. Leaves opposite-decussate, petiolate; petiole 2.3–3.8 cm long, pubescence as same as in stem. Lamina 8.7–14.8 × 3.0–6.2 cm long, ovate, apex long acuminate, decurrent at base, margin entire, abaxial surface covered with dense tawny-coloured woolly indumentum, adaxial surface glabrous; venation reticulated; nerves 9–11 pairs, arcuate, parallel with invisible reticulations, prominent on both surfaces while less in adaxial surface comparatively. Inflorescence spike, axillary and terminal, simple or branched, 1–3 branches, narrowly cylindrical, 26–70 × 3.5–5 mm, interrupted; peduncle 1.0–1.5 cm long, densely covered with tawny tomentose indumentum. Bract single, 4.5–4.8 ×1.5–1.6 mm long, shorter than calyx, ovate, green, apex acuminate, margin entire, adaxial surface and margins with dense tawny woolly indumentum. Bracteole 2, ca. 3.5mm long. Flower 2–2.2 cm long, blue, covered with soft tawny hairs, sessile. Calyx 5-lobed, unequal, 2 or 3 lobes are larger than the rest, 5.6–6.5 mm long, lobes lanceolate, acuminate or acute at apex, margin entire, adaxial surface covered with simple white delicate hairs, abaxial surface densely covered with tawny indumentum, similar to that of bract. Corolla 5-lobed, equal, overlapping, 5.5-5.7 × ca. 0.5 mm long, ovate to broadly triangular, round or rarely acute at apex, margins almost entire, blue, throat campanulate, outer surface with soft tawny tomentose indumentum; tube 14.0–15.5 mm long, ventricose, outer surface with soft tawny hairs. Stamens 2, equal, included; filaments 10–10.2 mm long, sparsely white hairs at base; anthers ca 1.8mm long, dithecous, dorsifixed. Ovary 2-celled, superior, on a prominent disc, ca. 1.5mm long, oblong, glabrous. Style ca. 9.5mm long, pubescent; stigma 2.5mm long with sparsely white hairs. Capsule 14–15 mm long, elliptic to narrowly obovate, glabrous. Seeds 2.2–4.5 mm long.

Phenology: October–June.

Distribution and Ecology: Found in thick rainforest undergrowth and shades of open grassland in the evergreen forest. The distribution of the species is strictly restricted to Tamil Nadu and Kerala (based on present collection) region of Western Ghats.

Additional specimens examined: India: Tamil Nadu. Nilgiri Dist., 6000ft. alt., xi.1883, Gamble, 13387 (BM!); Kerala. Palakkad District, Way to Elival Hills, 12.xi.2016, K.M. Prabhukumar & Binu Prakash, 9879 (CMPR!).

Reinstatement of *S. pushpangadanii*: In the protologue of *Strobilanthes lawsonii,* Gamble (1923) cites four materials, two from Sispara Ghat of Nilgiri Hills (Gamble 13387, 14252), one each from Thamracheri Ghat of Wayanad (Barber 5686) and Travancore hills (Bourdillon 42), however, the collection from Wayanad and Travancore hills is now considered representing two distinct species *S. gamblei* and *S. pushpangadanii*, respectively.

Carine et al. (2004) did an excellent revision of *Strobilanthes kunthiana* group in peninsular India with an understanding morphological comparison chart to distinguish the members among the group. As per the protologue, hand drawing of flower on the type specimen (Gamble 13387; lectotype designated by Carine et al. (2004) and Isolectotype) and the present collection from Muthikulam Hills (9879), it is very clear that, *S. lawsonii*

Image 1. *Strobilanthes lawsonii* Gamble.: A,B—Habit | C—inflorescence showing flowers with equal corolla lobes.

Figure 1. Illustration of *Strobilanthes lawsonii* Gamble.: A—Habit | B—flower | C—L.S. of flower | D—bract- adaxial view | E—bract-abaxial view | F—bracteole-adaxial view | G—bracteole-abaxial view | H—calyx | I—ovary | J—capsule | K—seed.

is distinct from *S. gamblei* and *S. pushpangadanii* by means of its equally divided corolla lobes. But during the revisionary work of *Strobilanthes* in peninsular India, Venu (2006) synonymised *S. gamblei* and *S. pushpangadanii* under *S. lawsonii* with commenting "*S. lawsonii* looks very similar and stands between *S. pushpangadanii* and *S. gamblei*". But he completely ignored the most notable morphological feature of this group, fusion of corolla lobes, exsertion of stamens, and pubescence nature of style. Based on the evidence of live collections and strong distinguishing characters between the taxa, status of *S. pushpangadanii* as a distinct species (Table 1 & Image 2). The latter species, *S. gamblei* (Image 3) has been recently reinstated by Pradeep et al. (2020).

Special notes: Augustine (2018) used a few photographs of the above discussed taxa provided by PKM with due acknowledgment.

Strobilanthes pushpangadanii E.S.S. Kumar, Jabbar & A.E.S. Khan, Rheedea 12: 73. 2002. (Image 2).

Type: India. Kerala. Thiruvanthapuram district, Mankayam hills, *E.S.S. Kumar* 14722 (Holotype: TBGT; Isotype: MH, CALI!)

Flowering & Fruiting: August–March.

Distribution and Ecology: Margins of evergreen forest and open grasslands in Kerala. Carine (2004) noted that the distribution of the species is strictly restricted to Thiruvananthapuram and Idukki districts of southern Kerala, but our field surveys reveal that the occurrence of the species extends up to the Palakkad gap.

Additional specimens examined: 14722 (CALI!, Isotype), India, Kerala, Thiruvananthapuram District, Mankayam Hills, 800m, 20.x.1992, coll. E.S. Santosh Kumar; 14030 (CALI!), Idukki District, Vellimala, 1,700m, 20.viii.1994, coll. Augustine; 11157 (CALI!), Thiruvananthapuram District, Ponmudi, Barnes s.n (K!); 5936 (KFRI!), Chemingi, c. 900m, 24.i.1992, coll. Mohanan; Thrissur District, Sholayar, 25.x.1992, coll. N. Sasidharan; 9879 (CMPR), Palakkad District,

Image 2. *Strobilanthes pushpangadanii* E.S.S. Kumar et al.: A—habit | B—inflorescence showing flowers with unequal corolla lobes.

Table 1. Comparison of morphological features of *Strobilanthes lawsonii*, *S. gamblei*, and *S. pushpangadanii*

Character	*S. gamblei*	*S. pushpangadanii*	*S. lawsonii*
Young stem	quadrangular	cylindrical	quadrangular
Petiole length	3–9 cm	1.5–2 cm	2.3–3.8 cm
Leaf size	5.5–15 × 2–6 cm	3.2–12 × 1–4.5 cm	8.7–14.8 × 3.0–6.2 cm
Leaf apex	long acuminate	caudate - acuminate	long acuminate
Leaf margin	entire	denticulate	entire
Leaf abaxial surface	densely covered with cream or tawny-colored woolly indumentum	abaxial soft silky texture due to the presence of dense tawny indumentum	abaxial surface covered with dense tawny-colored woolly indumentum
Leaf adaxial surface	glabrous	coriaceous, glabrous or sparsely pilose above	glabrous
Nerves (pairs)	6–11	7–13	9–11
Inflorescence type	interrupted	uninterrupted	interrupted
Inflorescence dimension	4–15 × 0.2–0.4 mm	5.5–6.2 × 0.5–0.8 mm	26–70 × 3.5–5 mm
Peduncle length	1–1.5 cm long	2.3–6.5 cm long	1–1.5 cm long
Bracts	glandular golden brown woolly indumentum outside	glandular golden brown woolly indumentum outside	adaxial surface and margins with dense tawny woolly indumentum
Bracteole	tawny woolly indumentum abaxially	golden brown woolly tomentose abaxially	tawny woolly indumentum abaxially
Calyx length	7.7–10.2 mm long	4–6 ×1–1.5 mm long	5.6–6.5 mm long
Calyx	glabrous or rarely hairy with tawny tomentose	dense tawny tomentose abaxially and adaxial glabrous	adaxial surface covered with simple white delicate hairs, abaxial surface densely covered with tawny indumentum
Corolla	light pink; 1.5–1.8 cm long, hairy	light pink with dark purple venation, 1.5–1.9 cm long, hairy	blue, outer surface with soft tawny tomentose indumentum
Corolla tube	1.1–1.3 cm long	1.0–1.2 cm long,	1.4–1.6 cm long
Corolla lobes	unequal, bi-lipped	unequal, bi-lipped	equal
Stamens	exserted	exserted	inserted
Filament	8.5 –11 mm long	ca. 2.2 cm	10-10.2 mm long
Style	glabrous	glabrous	pubescent

Key to the species

1a. Two partially fused corolla lobes, stamens exserted, style glabrous 2
1b. Corolla lobes divided equally, stamens included, style pubescent ..... *S. lawsonii*
2a. Leaves with up to 9cm long petiole and acuminate apex, margins entire, spikes uninterrupted, up to 6.5cm long, peduncle long, 2.3–6.5 cm long, corolla light pink ..... *S. gamblei*
2b. Leaves shortly petiolate up to 2cm long, apex short candidate-acuminate, margins denticulate or crenate-serrate, spikes interrupted, up to 10cm long, peduncle short, 1–1.5 cm long, corolla light pink with dark purple venation ..... *S. pushpangadanii*

Nelliyampathy, Minnampara, 12.xi.2016, coll. K.M. Prabhukumar & Binu Prakash.

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Image 3. *Strobilanthes gamblei* Carine et al.: A & B—habit (Inflorescence showing flowers with unequal corolla lobes).

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NAAS rating (India) 5.10

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Journal of Threatened Taxa

www.threatenedtaxa.org

PLATINUM OPEN ACCESS

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

March 2021 | Vol. 13 | No. 3 | Pages: 17847–18058
Date of Publication: 26 March 2021 (Online & Print)
DOI: 10.11609/jott.2021.13.3.17847-18058

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