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Caption: *Cnemaspis paripari*, photographed at Wind Cave, Sarawak © Indraneil Das.

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COMMUNICATION

Persistence of *Trachypithecus geei* (Mammalia: Primates: Cercopithecidae) in a rubber plantation in Assam, India

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Abstract: Non-human primates are highly threatened as a result of habitat destruction, agricultural expansion, industrial development, large-scale build-ups and wildlife trafficking. Nearly 60% of all primates are threatened and many are found in habitats with some form of human modifications (e.g., croplands and plantations). The adaptability of primates to survive in human-modified habitats is thus a key to determine their persistence in anthropogenic landscapes. In this study, we examined the population number and age-sex composition of the 'Endangered' Golden Langur *Trachypithecus geei* in a rubber plantation in the Kokrajhar District in Assam, India in 2016, and compared with past data of the langur population and demographics from the same location to better understand the population dynamics, demographic characters and persistence of the Golden Langurs in the rubber plantation. In 2016, we recorded six groups of Golden Langurs totaling 78 individuals with a mean group size of $13.00 \pm 4.00_{SD}$. Of the total population, 10.29% were adult males, 41.18% were adult females, 32.35% were juveniles and 16.18% were infants. The overall population growth from 1997 to 2016 was estimated to be 5.54% per year. Habitat matrices of rubber plantations with natural forest patches are important in the fragmented landscape for the persistence of Golden Langur populations. They may also act as a corridor for the langurs to move between the fragments and as food resources, highlighting the importance of such matrices for the langurs outside protected areas. Population monitoring and ecological studies in such matrices would therefore be needed for the successful implementation of targeted management strategies for the conservation of these threatened langurs.

Keywords: Anthropogenic landscape, landscape supplementation, matrix, persistence, primate.

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Author contributions: JS—conceptualisation of the study, data collection-compilation-analysis, and writing of the manuscript; JB—data collection, conceptualisation, executing the study and fundraising; SN—data collection; HNK—guiding the data compilation-analysis, writing manuscript.

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INTRODUCTION

Forest loss and habitat degradation that is primarily driven by agricultural expansion and intensification (Gibbs et al. 2010; Foley et al. 2011), are the major threats to biodiversity (Maxwell et al. 2016). This anthropogenic modification of ecosystems is globally widespread, resulting in many primate species living in human-modified landscapes (Cowlishaw 1999; Cowlishaw & Dunbar 2000; Chapman & Peres 2001) with remnant patches of natural vegetation (Prevedello & Vieira 2010; Watling et al. 2011). Non-human primates are most affected by anthropogenic habitat disturbance, partly due to their high dependence on tropical forest ecosystems (Isaac & Cowlishaw 2004). Nearly 60% of the world's primate species distributed in the Neotropics, mainland Africa, Madagascar, and Asia are threatened with extinction as a result of habitat destruction, agricultural expansion, industrial development, large-scale build-ups and wildlife trafficking (Estrada et al. 2017). In many parts of Asia, lowland dry evergreen and semi-evergreen forest and dry deciduous forests have been converted to plantations such as rubber and oil palm plantations (McKenney et al. 2004; Tordoff et al. 2005). The adaptability of primates to survive in human-modified habitats is a key to determine their persistence in anthropogenic landscapes (Ferreira et al. 2018). While some primates are known to use part of human-altered land covers (Pielke Sr. et al. 2004; Davey 2006; Wickham et al. 2012), others use degraded habitats and persist (e.g., Capped Langur *Trachypithecus pileatus*: Borah et al. 2021). But the lack of information on their ecological traits to utilize human-modified habitats greatly limits our ability to implement targeted landscape management strategies for their conservation.

Golden Langur *Trachypithecus geei* (Khajuria, 1956) is 'Endangered' (IUCN Red List; Das et al. 2020) and endemic to parts of Bhutan and the Indian state of Assam (Wangchuk 1997; Choudhury 2002). In India, the natural habitat of Golden Langur is primarily semi-evergreen and moist deciduous forests (Champion & Seth 1968; Bahuguna et al. 2016). A large part of the habitat of the Indian population of Golden Langurs has been lost in the last three decades and the population has been threatened (Srivastava 2006a). Several populations are confined to isolated forest fragments (Srivastava et al. 2001a; Choudhury 2002; Srivastava 2006b). Large-scale built-up areas and anthropogenic land-use patterns have changed the landscape and divided the Golden Langur population in India into two parts, viz., the northern and southern populations without contiguous habitats between them (Srivastava et al. 2001b). The northern population has a vast pristine area in Ripu Reserved Forest, Chirang Reserved Forest, and Manas National Park (>500 km^2) and is connected to the langur population in Bhutan. On the other hand, the southern population is confined to small habitat fragments (<50 km^2) with one subpopulation inhabiting a Rubber *Hevea brasiliensis* plantation in Nayekgaon in the Kokrajhar District in Assam, India. This rubber plantation and its fringe forests were once connected with the Chakrashila Wildlife Sanctuary, which is still a natural and protected habitat of the southern population of Golden Langurs. Over the course of time, the area lost its continuity with the Chakrashila Wildlife Sanctuary due to human settlement in adjacent forest areas (Medhi et al. 2004). In this study, we examined the population number and age-sex composition of Golden Langurs in the rubber plantation and surrounding areas in Nayekgaon in 2016, and compared with past data of the population and demographics from the same location so as to assess population trend and persistence of the Golden Langur in a small and isolated human-modified landscape. Previous studies were conducted in 1997 (Srivastava et al. 2001a), 2002 (Medhi et al. 2004), and 2008 (Ghosh et al. 2009) but detailed information was not available for the years 1997 and 2008 and hence we could only compare in detail with the 2002 data. Understanding the survival possibilities of such a population outside their natural habitat would help in primate conservation and habitat management.

METHODS

Study Area

The rubber plantation and its surrounding plantation areas consist of approximately 277 ha and is situated between 26.350–26.374 ^{0}N and 90.372–90.393 ^{0}E in Nayekgaon Village of the Kokrajhar District, Assam, India. The rubber plantations started in 1985 and Golden Langurs were also reported at the same time which indicated that the area was once the natural habitat of Golden Langurs (Medhi et al. 2004). The area is a private rubber plantation and comprises of 80% rubber plantation and 20% natural forests with human settlements and roads (Medhi et al. 2004). *Shorea robusta, Tectona grandis*, *Bauhinia purpurea*, *Bauhinia variegata*, *Mangifera indica, Dillenia pentagyna, Duabanga grandiflora, Litsea glutinosa, Terminalia bellirica, Premna bengalensis, Albizia procera, Stereospermum personatum*, and *Ficus* spp. are the

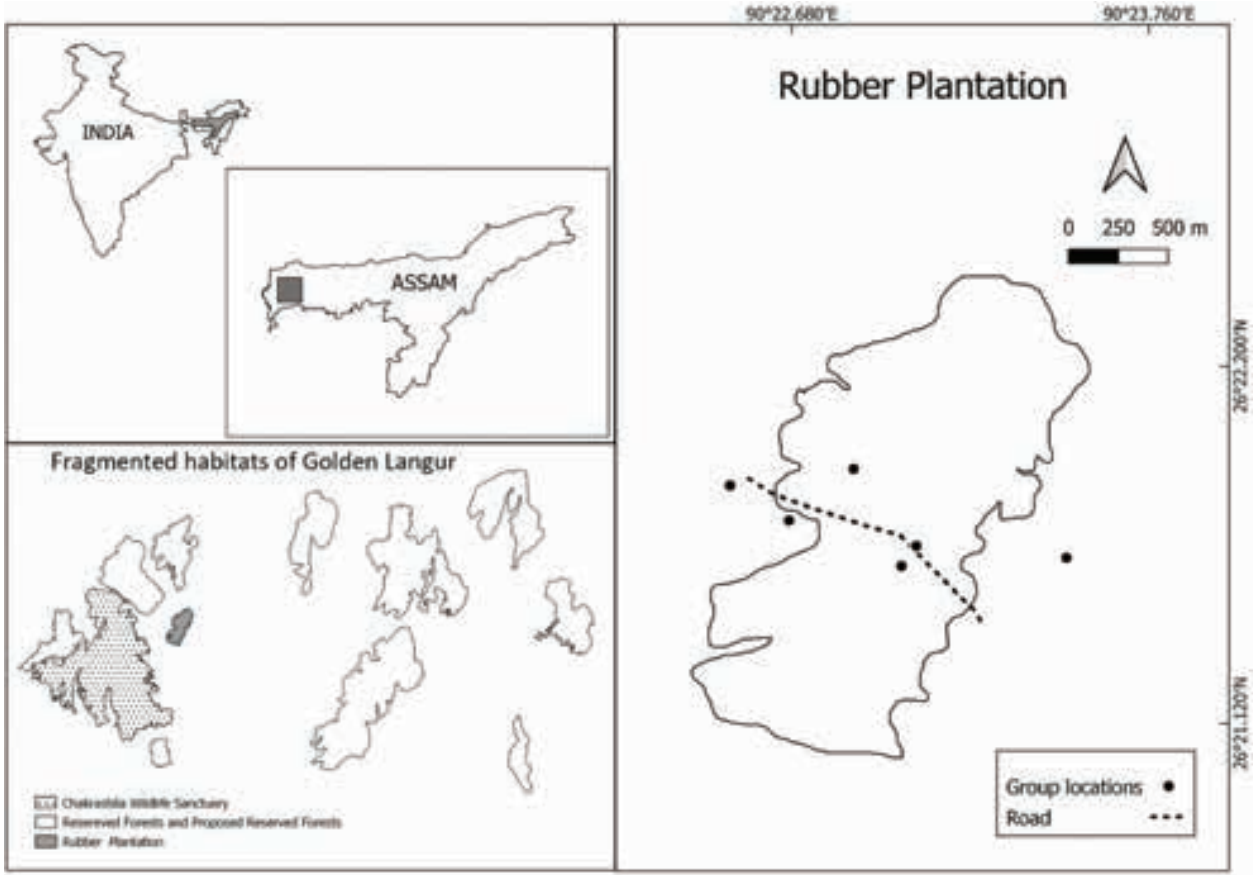

Figure 1. Abhaya rubber plantation in Nayekgaon Village of the Kokrajhar District, Assam, India

Image 1. Golden Langur in the rubber plantation. © Joydeep Shil.

Image 2. Golden Langur in the rubber plantation. © Joydeep Shil.

main species within the natural vegetation (Medhi et al. 2004). During our study, we also recorded roughly 20% of the area consisting of natural forests. Our interaction with the plantation manager confirms that there was no further expansion of rubber plantation after 1985. Climatic conditions of the area are humid with moderate temperature with high rainfall during monsoon and dry with low temperature during winter (Barthakur 1986). The annual rainfall of the area is between 2,000 and 3,000 mm. Rhesus Macaques *Macaca mulatta* are sympatric with the langurs (Medhi et al. 2004). A study area map (Figure 1) was created using QGIS 3.16.

Survey

Since the area of Nayekgaon rubber plantation is small, total count was possible. We followed the same field protocol as the previous population assessment in the same location in 1997 (Srivastava et al. 2001a, 2002; Medhi et al. 2004, 2008; Ghosh et al. 2009), i.e., block count methods (Struhsaker 1975; Burnham et al. 1980; NRC 1981) for a total count of the population. The area was demarcated into two blocks by taking the road as a landmark (Figure 1). The road passes from east to west through the rubber plantation and divides the area almost equally. Each block was further divided into sub-blocks of 12 to 15 ha. Prior to the survey, a one-day training workshop was conducted for the recording of geo-coordinates and population assessment including age-sex of the individuals of Golden Langurs. The teams were led by a trained biologist who was able to differentiate the age and sex of individuals of Golden Langurs. The assessment was conducted by 12 teams consisting of two people in each team. Each sub-block was surveyed by a team of two people either in the morning or in the evening. All the teams walked in parallel maintaining at least 200 m distance between each team from 0600 to 1100 h and from 1400 to 1700 h on three consecutive days from 26 to 28 February 2016. Each team was provided with a handheld GPS (Garmin 78S), 8×4 binocular, digital camera and Motorola wireless handset for communication to avoid duplication in counting. When langurs were encountered, we recorded the geo-coordinates of the location of the group, and observed the group for sufficient time or until we could record the total number, and age-sex of all the individuals in the group. The data on age and sex were considered as adult male (AM), adult female (AF), juvenile (JU), and infant (IN). Visibility was high in the rubber plantation so there were no difficulties in locating the animals. The langurs were habituated to human presence since they regularly came into contact with plantation workers and researchers.

Data analysis

The groups were differentiated and identified using the time, location, and group composition of adjacent groups. Since the area was small, we adapted the total count method, and the sum of the number of individuals in each identified group was considered as the number of individuals in the study area. We calculated the density as a total number of individuals in the total area.

The data of adult males and adult females were combined to represent adults (AD) and the same was done for infant and juvenile, represented as immature (IM), to compute the age-sex ratios. We calculated the mean group size, mean individual of different age-sex classification, and age-sex ratios using the data of all the groups. We could not identify the age and sex of four of the individuals in one of the groups, thus that group was not considered in the calculation for the mean age-sex compositions but was considered for the total count and mean group size. We compared the data of 2002 and 2016 to check for any significant differences. We did not consider other year's data since it was not completely available. We compared the mean group sizes using the Mann-Whitney U test, the proportions of different age-sex compositions using the Chi-square test, and the ratios of different age-sex using Paired Wilcoxon Signed Rank test. The density of langur was calculated as a total number of individuals divided by the total area of the survey (~277 ha). We used statistical analysis using R version 3.6.3. The rate of population growth, r, between two-time points, t1 and t2, is calculated as a rate of growth, expressed in percentage units per year:

$$r = \frac{\left(\frac{P2 - P1}{P1}\right) x100}{t2 - t1}$$

Where P1 and P2 are the number of individuals at times t1 and t2 respectively and the time interval (t2-t1) is expressed in years (https://pages.uoregon.edu/rgp/PPPM613/class8a.htm Accessed on 12 March 2021).

RESULTS

We recorded six groups of Golden Langurs totaling 78 individuals (Table 1, Image 1&2) with the mean group size of $13.00 \pm 4.00_{SD}$ (Table 2). By excluding the data from Group 1 where we were unsure of the demographics of some of the individuals, the age-sex composition of the population was 10.29% (N= 7) adult males, 41.18% (N= 28) adult females, 32.35% (N= 22) juveniles and 16.18% (N= 11) infants. Of the six groups, three groups had two adult males. The ratio of adult male to adult female was 1:4.00; adult to immature was 1:0.94; and adult female to infant was 1:0.39 (Table 2). The calculated density showed 28.16 langurs/km^2.

The number of groups recorded in 1997 was five, declined to three by 2002 (Medhi et al. 2004), increased to 12 by 2008 and then declined to six by 2016 (Table 2). The mean group size between 2002 and 2016 did not vary significantly (M-W U test, U= 12.0, p= 0.517). Proportion of adult males, adult females and immature per group in 2002 and 2016 (adult males: χ^2= 2.88, df= 7, p= 0.896; adult females: χ^2= 10.34, df= 7, p= 0.17; immature: χ^2=

Table 1. Group compositions of *Trachypithecus geei* in rubber plantation in 2016.

Group #	Adult male	Adult female	Juvenile male	Juvenile female	Infant	Unidentified/ Doubtful	Total
1	2	2	1	1	0	4	10
2	1	6	1	2	2	-	12
3	1	4	2	2	0	-	9
4	2	8	2	1	5	-	18
5	2	6	4	4	2	-	18
6	1	4	1	3	2	-	11
All total							78

Table 2. Group size, age-sex composition of *Trachypithecus geei* in rubber plantation in different studies.

Group parameters	1997 (Srivastava et al. 2001a)	2002 (Medhi et al. 2004)	2008 (Ghosh 2009)	2016 (current study)
Total groups (mean group size±SD; range)	5 (7.6)	3 (17.33±9.61; 7–29)	12 (9.3)	6 (13.00±4.00; 9–18)
Total AM (mean±SD; range)	-	5 (1.67±0.58; 1–2)	-	7 (1.40±0.55; 1–2)
Total AF (mean±SD; range)	-	17 (5.67±3.21; 2–8)	-	28 (5.60±1.67; 4–8)
Total IM (mean±SD; range)	-	30 (10.00±6.00; 4–16)	-	33 (6.60±2.41; 4–10)
AM:AF	-	1:3.40	1:2.25	1:4.00
AD:IM	-	1:1.36	-	1:0.94
AF:IN	-	1:0.76	-	1:0.39
Total individuals	38	52	112	78

Table 3. Population growth rate of *Trachypithecus geei* in rubber plantation.

Period	Annual Growth rate %
1997–2002	7.37
2002–2008	19.23
2008–2016	-3.79
1997–2016	5.54

6.91, df= 7, p= 0.438) did not vary significantly (Table 2). Although, the number of females per male in 2002 (3.40) was less than in 2016 (4.00) the difference was not significant (t= -1.313, df= 6, p= 0.237). Similarly, the number of immatures per adult (in 2002: 1.36 and in 2016: 0.94; t= -0.844; df= 6, p= 0.431), and number of infants per adult female (2002: 0.76 and 2016: 0.39; t= 2.144; df= 6, p= 0.076) did not differ significantly. The population growth between 1997 and 2016 was found to be 5.54 % (Table 3).

DISCUSSION

We examined the population numbers and demographics of the Golden Langur in a rubber plantation in Assam, India between 1997 and 2016. Although the reasons for the differences in the number of groups and the mean group size between the study period were not well understood due to the lack of continuous monitoring, the fluctuations in the population size could be tracked during certain periods. The large group size in 2002 and the small group size in 2008 with many groups indicated that the population might be exhibiting fusion and fission of the groups. Fusion and fission of groups are social traits in primates, and also reported in Golden Langur (Biswas 2004). Group size influences feeding time (Doran 1997; Sakura 1994), suggests that fission-fusion may serve as a mechanism to reduce within-group feeding competition and help to overcome the negative consequences of group living. Absence of the significant difference in age-sex ratios between 2002 and 2016 suggests that though the population size fluctuated, the demographical structures remained stable despite changes in vegetation structure and species composition in the habitat. Within the natural habitat of Chakrashila Wildlife Sanctuary, the group size of Golden Langur ranged 3–15 individuals, with a mean size of 7.4 and the age structure of the population comprised 49.8% adults, 33.5% juveniles and 16.7% infants (Chetry et al. 2010). Our study, however, shows

that the density of Golden Langur in a rubber plantation (28.16 langurs/km^2) is much higher than in the natural habitat of Chakrashila Wildlife Sanctuary (12.40 langurs/km^2) (Chetry et al. 2020). The annual population growth from 1997 and 2016 (Table 3) was much higher (5.54%) than in the natural habitat of Chakrashila Wildlife Sanctuary i.e., 1.5% annual growth from 2006 (Chetry et al. 2010) to 2016 (Chetry et al. 2020). In the rubber plantation, deaths of three adult female Golden Langurs due to electrocution in 2001–2002 were reported by Medhi et al. (2004). Medhi et al. (2004) also mentioned domestic dogs as a possible threat for the Golden Langur population. This could affect the population dynamics and age-sex composition since the population of Golden Langur is small. But during this survey and our behavioral study period (2013-2016) we did not record any incident of electrocution or dog attack. The birth rate and immature survival rate were not different between the rubber plantation and adjacent natural forests of Chakrashila Wildlife Sanctuary (Shil et al. 2020). Since the birth and immature survival rate cannot be a factor of population fluctuation in the rubber plantation, therefore migration of animals could be the possible reason. Furthermore, the high nucleotide diversity of the langur population at Nayekgaon's rubber plantation (Ram et al. 2016) indicated that gene flow between the populations of other nearby fragments was probably still present. Rubber monocultures can provide corridors for the movement of Golden Langurs between fragmented habitats as canopy connectivity reduces the exposure of primates to predators (Oliveira & Dietz 2011; Cassano et al. 2014; Coleman & Hill 2014).

In areas where natural habitats have declined, primates may be forced to use altered landscapes of a matrix composition more frequently for feeding and traveling (Galán-Acedo et al. 2019). Rubber agroforests that retain some degree of natural forests support a subset of forest biodiversity in landscapes (Warren-Thomas et al. 2015). The encounter rate of Spider Monkeys *Ateles geoffroyi* increased with matrix functionality in the more disturbed region (Galán-Acedo et al. 2019). Feeding on young leaves and fruits of rubber (Roy & Nagarajan 2018) and dry rubber seeds by Golden Langurs (Medhi et al. 2004; Roy & Nagarajan 2018) and use of rubber trees for sleeping (Roy & Nagarajan 2018) highlight an adaptive behavior of the langurs. In Sumatra, Rizaldi et al. (2019) reported six out of nine groups of East Sumatran Banded Langur *Presbytis percura* adapting to feed on non-native rubber trees which were introduced into their habitat nearly 100 years ago. At least 86 primate species (17% of all primates) are actively obtaining food resources from the anthropogenic landscape, highlighting their importance for primate conservation (Asensio et al. 2009; Arroyo-Rodríguez et al. 2017). Among forest-specialised primates, which represent 70% of the studied species, the results suggest that the reason for the persistence of their population in the altered habitat may be because they are able to supplement their diet by foraging in the modified landscape (Dunning et al. 1992). In Batang Serangan in northern Sumatra, a small population of the Sumatran Orangutan *Pongo abelii*, Thomas's Langur *Presbytis thomasi*, Long-tailed Macaque *M. fascicularis fascicularis*, Southern Pig-tailed Macaque *M. nemestrina*, Lar Gibbon *Hylobates lar*, and Silvered Langur *T. cristatus* have been reported living for several decades in a mixed agroforest system composed of Oil Palm *Elaeis guineensis*, rubber trees, and remnant forest (Campbell-Smith et al. 2010). The continued presence of Proboscis Monkey *Nasalis larvatus* for more than two decades in the cocoa and oil palm plantation in Lower Kinabatangan Floodplain suggests that the species is resilient to habitat changes (Boonratana 2013). But the loss of critical habitats and the inability to access other nearby fragments have allowed the species to persist only at lowered population size and densities, and with likely changes to their behavior and ecology (Boonratana 2013). The rate of emigration from habitat also had a very strong predicted effect on the extinction threshold; the higher the rate of emigration, the more habitat was needed for persistence (Fahrig 2001). Angolan Colobus *Colobus angolensis palliatus* frequently travelled and foraged in indigenous matrix vegetation (such as mangrove, wooded shrubland, and shrubland) up to four kilometers from the nearest forest fragments. Agricultural habitats, such as perennial plantation (coconut, mango and cashew nut) was also used by colobus as corridor (Anderson et al. 2007). Although initial decline in the population was observed, Golden Langurs have shown increase in the population size over the period. A similar pattern was also seen with other primates e.g., Nicobar Long-tailed Macaque *M. f. umbrosus* in Nicobar Islands (Velankar et al. 2016), Lion-tailed Macaque *M. silenus* in Western Ghats (Umapathy et al. 2011), Guerezas *Colobus guereza* and Blue Monkey *Cercopithecus mitis* in Kakamega forests in Kenya (Mammides et al. 2008). Thus, the persistence of Golden Langur in a relatively high density in the rubber plantation could be due to continued gene flow between nearby populations and the value of the rubber plantation as food resource and habitat corridor amid a disturbed, anthropogenic landscape outside of protected areas. Continuous population monitoring and ecological

studies in such matrices would help in understanding their adaptability for the conservation of the threatened Golden Langur.

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Population assessment of the endangered Western Hoolock Gibbon *Hoolock hoolock* Harlan, 1834 at Sheikh Jamal Inani National Park, Bangladesh, and conservation significance of this site for threatened wildlife species

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Abstract: Sheikh Jamal Inani National Park (Inani) is a wildlife habitat in Bangladesh located under the Cox's Bazar South Forest Division, Cox's Bazar. It constitutes significant habitat for the charismatic and globally 'Endangered' Western Hoolock Gibbon *Hoolock hoolock* in Bangladesh. Here, we show that Inani is a poorly-known gibbon habitat with a population of seven groups, comprising a total of 18 individuals. Among them, 77.8% were adults (males and females), and 11.1%, 5.6%, and 5.6% were sub-adults, juveniles, and infants, respectively, indicating low reproductive output. Five of seven groups had no offspring present in the group, and the mean group size of 2.57 individuals/group is low compared to other habitats in Bangladesh. Beside Western Hoolock Gibbon, Inani is home to many threatened wildlife species. The first record of the Slaty-backed Flycatcher *Ficedula erithacus* in Bangladesh occurred in Inani, adding this new species to the national bird checklist of Bangladesh. The presence of the globally 'Endangered' Asian Elephant *Elephas maximus*, Phayre's Langur *Trachypithecus phayrei*, & Elongated Tortoise *Indotestudo elongata* and the globally 'Vulnerable' Northern Pig-tailed Macaque *Macaca leonina*, Capped Langur *Trachypithecus pileatus*, Indian Leopard *Panthera pardus*, & Asiatic Softshell Turtle *Amyda cartilaginea* highlight the importance of Inani as a conservation area in Bangladesh. The Western Hoolock Gibbon and other threatened wildlife of Inani are now on the verge of local extinction due to a sharp increase in forest resource extraction resulting from the recent influx of large numbers of Rohingya refugees from Myanmar, many of whom have settled around Inani. Through stakeholder interviews in the area, we have identified feasible and measurable conservation actions at Inani that are urgently needed to prevent further loss of wildlife and to protect this important gibbon habitat.

Keywords: Cox's Bazar South Forest Division, Rohingya, Slaty-backed Flycatcher.

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INTRODUCTION

Sheikh Jamal Inani National Park (short: Inani) is the southern-most natural, although heavily degraded, forest in Bangladesh. It was previously known as Inani Reserved Forest, and was declared a National Park in 2019 by the Bangladesh Government. Inani includes the last remnants of degraded natural forest in Cox's Bazar South Forest Division and supports many globally threatened wildlife species (Kabir et al. 2014, 2015, 2017). These forests also form a wildlife corridor between Myanmar and Bangladesh that is recognized in Bangladesh as a prominent Asian Elephant corridor (IUCN Bangladesh 2018).

Rohingya refugees are defined by the People's Republic of Bangladesh as 'forcibly-displaced Myanmar nationals' (UNDP Bangladesh and UN WOMEN Bangladesh 2018). About a million Rohingya refugees have settled in Bangladesh in successive waves of displacement since the early 1990s (https://www.unhcr.org/rohingya-emergency.html), of which 716,915 are new arrivals since 25 August 2017 (https://data2.unhcr.org/en/situations/myanmar_refugees). They have settled at Ukhia and Teknaf upazila (sub district) under the Cox's Bazar District of Bangladesh. The majority of them have settled around or inside the Ukhia Reserved Forest, Sheikh Jamal Inani National Park, and Teknaf Wildlife Sanctuary, administered by the Bangladesh Government and UNHCR. Makeshift camps and fuel-wood collection have had significant impacts on forested areas, resulting in forest degradation and habitat loss, wildlife habitat fragmentation, loss of wildlife corridors, and an increase in elephant-human conflict (UNDP Bangladesh and UN WOMEN Bangladesh 2018).

Several recent publications over the last 12 years describe wildlife diversity and conservation in Inani (e.g., Akhter et al. 2009; Ahmed et al. 2011; Rahman & Mannan 2011; Kabir et al. 2014, 2015, 2017; Haidar et al. 2017). Drastically decreasing habitat quality at Inani due to forest loss and other threats, such as encroachment and extraction of forest products by nearby local and Rohingya communities, however, are driving the Western Hoolock Gibbon, as well as other wildlife species, to the brink of local extinction.

No recent information has been published on the population status of Western Hoolock Gibbon *Hoolock hoolock* Harlan, 1834 at this site (Image 1). New information is provided in this paper on the population status of Western Hoolock Gibbons at Inani, and we report the occurrence of other globally threatened wildlife species, indicating the value of the site. Through stakeholder interviews in the area, we identified in situ conservation initiatives that should be undertaken immediately to protect Western Hoolock Gibbon and other threatened species at Inani.

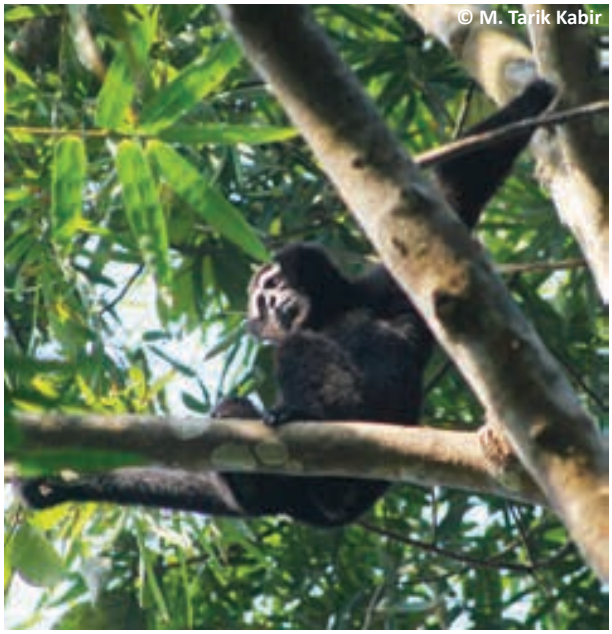

Image 1. Western Hoolock Gibbon *Hoolock hoolock*

MATERIALS AND METHODS

Study Area

The Sheikh Jamal Inani National Park (21.226642 N and 092.081416 E) covers an area of 7085.16 ha of hill forest in the Inani Forest Range under the Cox's Bazar South Forest Division of Cox's Bazar District of Bangladesh. It is bordered by the Himchhari National Park in the north, Teknaf Wildlife Sanctuary in the south, Ukhia Reserved Forest in the east, and the Bay of Bengal in the west.

The vegetation of Inani is mixed-evergreen forest dominated by degraded secondary forests. Major tree species are Garjan *Dipterocarpus* spp., Chapalish *Artocarpus chama*, Chundul *Tetrameles nudiflora*, Civit *Swintonia floribunda*, Telsur *Hopea odorata*, Shimul *Bombax* spp., Pitraj *Aphanamixis polystachya*, Koroi *Albizia* spp., Bandorholla *Duabhanga grandiflora*, Jam *Syzygium* spp., Rata *Amoora wallichii*, Nageshwar *Mesua ferrea*, Uri-am *Magnifera longipes*, Bhadi/Jiol *Lannea coromandelica*, Jarul *Lagerstroemia* spp., Gamar *Gmelia arborea*, Figs *Ficus* spp., and Ajuli *Dillenia pentagyna* (Kabir 2012).

The composition of the undergrowth, including bamboos, varies considerably from place to place. The most common species are Mulibansh *Melocanna bambusoides*, Mitinga *Bambusa tulda*, Ground Orchid

Geodorum spp., Galla Bet *Daemonorops jenkinsianus*, and Bet *Calamus* spp.. There is an abundance of creepers, lianas, and epiphytes, including *Tinospora cordifolia*, *Vitis* spp., *Spatholobus roxburghii*, *Entada pursaetha, Derris* spp., *Ipomoea* spp., *Passiflora* spp., *Oberonia* spp., and others.

Methods

Western Hoolock Gibbon habitats in Bangladesh consist only of small habitat fragments, in contrast to the larger, more continuous habitats of the species in other countries (Ahsan 1994; Geissmann et al. 2013; Ray et al. 2015). A gibbon population census was conducted by the total-count method and groups were detected at established listening posts (following Brockelman & Ali 1987; Cheyne et al. 2007; Brockelman et al. 2009). One observer sat at one listening post carefully noting the singing times and durations of singing bouts of gibbon pairs, taking compass bearings, and estimating the distance from the singing pair to the listening post. Upon visual encounters, observer(s) assessed the group composition. Adult males, adult females, subadult males, subadult females, juveniles, and infants were estimated on the basis of the body size and coat colour (Kakati et al. 2009), and behavioral pattern (Ahsan 1994). Groups were distinguished by location, group composition and distance between groups, and all groups identified were given a distinct identification number for long-term monitoring. Gibbon groups were monitored from January 2017 to January 2021 to confirm group compositions. Gibbon population monitoring was conducted from early morning to early afternoon (0600 to 1400 h) for a period of four consecutive days/month from October to April during the monitoring period. The occurrence of other threatened wildlife species was confirmed opportunistically through direct visual observations during field trips from January 2013 to January 2021.

Threat assessment was conducted through direct field observations and feasible conservation measures were identified in discussions with focus groups, including forest-dependent people, nearby communities and villagers, community patrol groups, local community leaders and other relevant stakeholders, such as forest department staff (BOBLME 2013; Alam et al. 2014). Three focus-group discussions (FGD) were conducted with the participants at Boro Inani, Patuartake, and Swankhali between March and June 2018. There were 10–12 participants in each FGD. Participants were selected in consultation with the local forest department and village headmen. Predefined questionnaires were completed to assess the perceived impact of the huge Rohingya influx to Inani and to identify possible conservation measures to save the wildlife at Inani, including its Western Hoolock Gibbons (Alam et al. 2014).

RESULTS

Seven groups of Western Hoolock Gibbons consisting of 18 individuals were confirmed to reside in Sheikh Jamal Inani National Park during the study period (Table 1). Six groups were reported from Inani Forest Beat (local administration unit of Bangladesh Forest Department) and one from Swankhali Forest Beat (Inani Forest Range). Only two of these groups (Groups 3 and 4) showed evidence of reproduction during the study period, including an adult pair with a subadult and an infant, and an adult pair with a subadult and a juvenile (Table 1). The mean group size was 2.57 individuals (n= 7). Synchronous singing by Groups 1, 2, 3, & 4 was heard at least twice,

Table 1. Group sizes and composition of Western Hoolock Gibbons at Shekih Jamal Inani National Park, Bangladesh in January 2021.

Forest jurisdiction	Area	Group number	Group composition						Total individuals
			AM	AF	SaM	SaF	Ju	In	
Inani Range	Inani Beat	1	1	1	-	-	-	-	2
Inani Range	Inani Beat	2	1	1	-	-	-	-	2
Inani Range	Inani Beat	3	1	1	1	-	-	1	4
Inani Range	Inani Beat	4	1	1		1	1	-	4
Inani Range	Inani Beat	5	1	1	-	-	-	-	2
Inani Range	Inani Beat	6	1	1	-	-	-	-	2
Inani Range	Swankhali Beat	7	1	1	-	-	-	-	2
Total			**7**	**7**	**1**	**1**	**1**	**1**	**18**

*AM—Adult male | AF—Adult female | SaM—Sub-adult male | SaF—Sub-adult female | Ju—Juvenile | In—Infant.

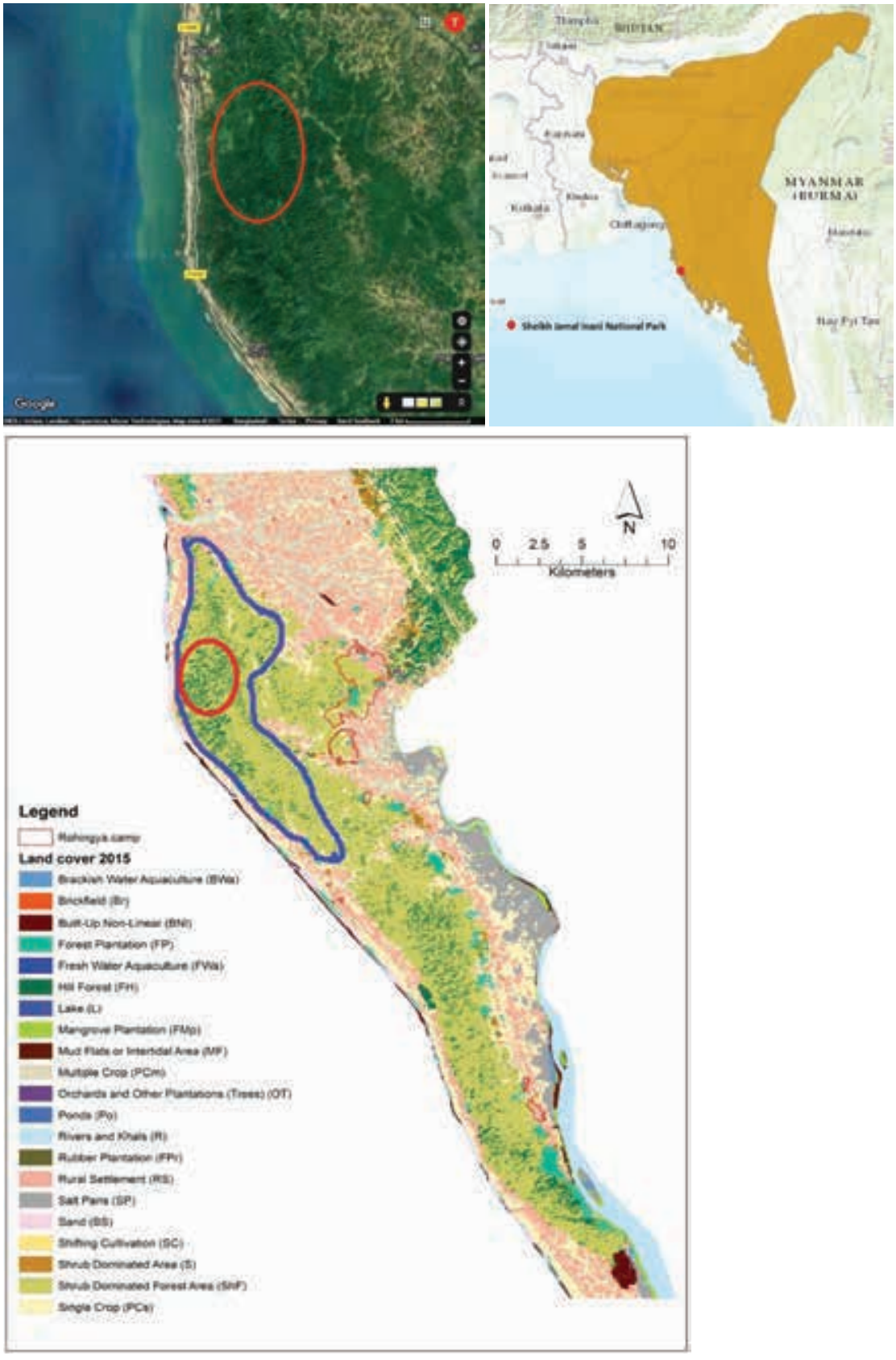

Figure 1. Sheikh Jamal Inani National Park. Top left: satellite image with proposed conservation core area (red area). Top right: IUCN distribution map of *Hoolock hoolock*. Bottom: Sheikh Jamal Inani National Park (blue outline) with proposed conservation core area (red circle). (Sources: top left: Google Earth; top right: www.iucnredlist.org; bottom: UNDP Bangladesh and UN WOMEN Bangladesh 2018)

which indicates that they were separate groups. The area inhabited by Groups 1–4 is considered as the core area for immediate conservation action (Figure 1). Groups 1, 2, 3, 5, 6, & 7 were first observed in 2014 during an opportunistic wildlife survey at Inani and at that time, each group consisted of only an adult male and female. Group 3 produced an offspring in early 2015 and again in January 2021.

Inani is a significant habitat for many globally threatened wildlife species, which also require immediate conservation initiatives. The presence of the Indian Leopard *Panthera pardus fusca* in Cox's Bazar District of Bangladesh was first confirmed in 2014 in the core gibbon habitat of Inani (Kabir et al. 2017), with additional sightings in 2017 and 2018 (M. Tarik Kabir, pers. obs. 2017 & 2018). During the gibbon surveys, we also made the first observations of the Slaty-backed Flycatcher *Ficedula erithacus* in Bangladesh (Image 2). It was identified by its orange underparts, deep blue upperparts and black tail with white base in males (Image 2). This species was previously reported as having a global distribution in Bhutan, China, India, Laos, Myanmar, Nepal, Vietnam, and Thailand (BirdLife International 2016) and now we confirm that its range extends into Bangladesh. It was first sighted in January 2014 in an area dominated by shrubs and homestead vegetation near human habitations and was sighted again at the same place in February 2016.

The globally 'Endangered' Asian Elephant *Elephas maximus*, Phayre's Langur *Trachypithecus phayrei*, & Elongated Tortoise *Indotestudo elongata* and the 'Vulnerable' Capped Langur *Trachypithecus pileatus*, Northern Pig-tailed Macaque *Macaca leonina*, Indian Leopard *Panthera pardus*, & Asiatic Softshell Turtle *Amyda cartilaginea* were also observed in the core gibbon habitat of Inani.

IUCN Bangladesh (2018) has estimated that the total population of elephants in the five forest ranges of the Cox's Bazar South Forest Division includes only 38 individuals (31–45). Elephants are now isolated in Inani, Ukhia, Shilkhali, Whykheong, and Teknaf forest ranges due to the blocking of the Ukhia-Ghundhum Elephant Corridor by Rohingya settlements since 2017 (Irfanullah 2018). Focus-group discussions with the relevant stakeholders showed that elephant-human interaction has dramatically increased at Inani, in the area of Mohammad Shafir Beel, after the recent influx of Rohingya refugees who live around the forest and collect firewood and other forest resources on an unsustainable level. The interviewees also agreed that the wildlife habitat of Inani will vanish in a short period of time if the current situation is not mitigated. Beside the negative impacts on wildlife and habitat quality resulting from the influx of refugees, the gibbon habitat in Inani has also been destroyed and degraded by illegal resource harvesting and encroachment by local communities and forest-dependent people. Local communities collect the stems of saplings of various tree species and use them as poles for their betel-leaf vineyards. The interviewees stated that they think that habitat destruction and degradation may be mitigated through regular patrolling of the forest department and with direct involvement of the local community, more dialogue among policy makers and the forest-living people, and an extensive habitat restoration programme.

DISCUSSION

The Western Hoolock Gibbon is a 'Critically Endangered' species in Bangladesh (IUCN Bangladesh 2015) and an 'Endangered' species globally (Brockelman et al. 2019). About 282 individuals were reported in Bangladesh in surveys over a decade ago (Islam et al. 2006). Islam et al. (2006) observed two groups of gibbons in the Inani Range and five in the Ukhia Range during eight-day (Inani) and nine-day (Ukhia) survey periods. Based on our survey results, it seems likely that Inani supported a larger gibbon population during the 2003–2004 survey period, and that not all gibbon groups were observed within the short survey period. Moreover, at that time, the habitat quality was much better than presently, but gibbons have now become locally extinct in Ukhia (M. Tarik Kabir, pers. obs. 2020).

It was revealed in this study that Sheikh Jamal Inani National Park supports the fourth largest population of Western Hoolock Gibbons in Bangladesh, after the larger populations in Lawachara National Park, Adampur Reserved Forest, and Kaptai National Park (Islam et al. 2006). Ahsan (2001) reported that the mean group size of Western Hoolock Gibbons was 3.0 (n= 8) at West Bhanugach in northeastern Bangladesh, whereas Feeroz & Islam (1992) estimated a mean group size of 3.17 (n= 6) in the same area. Comparison between group sizes in Inani and other habitats suggest a lower reproductive output at Inani. Loss of adequate food sources and changes in the habitat structures have led to low encounter rates and small group sizes at the fragmented Western Hoolock Gibbon habitats in eastern Assam, India (Kakati et al. 2009). Low population densities have also been reported among primates in Mexico and Brazil due to reduced food resources and habitat fragmentation (Estrada & Coates-Estrada 1996; Chiarello & Melo 2000). Gibbon habitat in

Image 2. A—Slaty-backed Flycatcher *Ficedula erithacus* from Inani, the first record of this species in Bangladesh | B—Western Hoolock Gibbon *Hoolock hoolock* at Inani | C—Pugmark of Indian Leopard *Panthera pardus* at Inani | D—Phayre's Leaf Monkey *Trachypithecus phayrei* at Inani | E—Fire wood collection from gibbon habitat in Ukhia | F—Loss of gibbon habitat at Ukhia. © M. Tarik Kabir.

Inani is highly degraded and fragmented without upper canopy trees, which is likely the main reason for their low reproductive output. We suggest that an extensive habitat restoration programme (Hossain et al. 2008) and the total protection of gibbon habitats at Inani are required to ensure the survival of the gibbons in this area.

Many globally threatened wildlife species, including the Western Hoolock Gibbon, are now on the verge of extinction at Inani due to sharply increased pressure on natural forest resources due to the recent influx of large numbers of Rohingya refugees from Myanmar into the area. The total number of registered Rohingya refugees in Cox's Bazar district is 866,457, according to the Bangladesh Government and UNHCR, of which 716,915 are new arrivals since 25 August 2017 (https://data2.unhcr.org/en/situations/myanmar_refugees).

Refugees have temporarily settled in the area by clearing forests on both sides of the Cox's Bazar-Teknaf highway, mostly residing in the fringes of Ukhia Reserved Forest, Inani and Teknaf Wildlife Sanctuary, which is increasing human-wildlife conflict in the area (Irfanullah 2018). About 3,713 acres of forest land were completely cleared to make Rohingya settlements in Ukhia, Whykheong, and Teknaf forest ranges in 2017 (UNDP Bangladesh and UN WOMEN Bangladesh 2018). According to the Bangladesh Forest Department, an additional 6,163 acres of forest land was damaged in the areas affected by Rohingya settlement, with no up-to-date information on the habitat status (ADB 2019).

Deforestation and forest fragmentation, changes

in forest cover, biomass reduction, loss of species, loss of wildlife habitat, shrinkage of wildlife corridors and increased mortality risk for wildlife are expected to result from the large influx of migrants into Inani (UNDP Bangladesh and UN WOMEN, Bangladesh 2018). The area influenced by Rohingya refugees is estimated to cover 44% of the 60,000 ha landscape encompassing Sheikh Jamal Inani National Park, Ukhia Forest Range and Teknaf Wildlife Sanctuary (UNDP Bangladesh and UN WOMEN Bangladesh 2018), putting enormous pressure on this landscape and the remaining forests. For example, an estimated 6,800 tons of fuel wood is required each month by the refugee population, of which approximately 50% is collected from the forests (UNDP Bangladesh and UN WOMEN Bangladesh 2018). Fortunately, the Rohingya community does not hunt the gibbons. Liquefied petroleum gas (LPG) and improved cooking stoves have been distributed since August 2018 to Rohingya refugees and host communities to reduce the demand for firewood from the nearby forest (IUCN Bangladesh 2019). Firewood demand dropped by 79 % among the Rohingya families after the LPG was provided (IUCN Bangladesh 2019), but small-scale fuel-wood collection will continue to pose huge pressure on natural resources at and around Inani.

RECOMMENDATIONS

Western Hoolock Gibbons are likely to disappear from Sheikh Jamal Inani National Park in the near future, if the current trend of habitat destruction continues. The presence of large Rohingya refugee settlements have created a critical situation that puts pressure on threatened species. Management and conservation by the Bangladesh Forest Department of the whole of Inani is not possible due to socio-political issues and the pressure being placed on natural resources by people living around the forest. The Forest Department also has a shortage of manpower and other resources to protect the large forest area. Nonetheless, the following steps can be considered for protection and management of the gibbon habitats of Inani:

1. Community members are urged to take immediate action to demarcate one designated area of about 2,000 ha in the core gibbon habitat of Narikella Jhuri-Bairuntali (21.229074N, 92.070104E) as a totally protected zone. Regular monitoring and patrolling of this zone should be prioritized by the Bangladesh Forest Department as extensive monitoring and patrolling to the whole Inani area is not possible;
2. Any resource harvesting from this core areas should be strictly prohibited and wide public awareness campaigns must be organized to develop a positive response among the forest-dependent people, especially fuel and timber wood collectors;
3. Regular patrolling and habitat monitoring by the Forest Department should be conducted in partnership with community patrol groups, comprising community members and local leaders, to create a sense of stewardship and enhance protection of forests as well as wildlife;
4. Highly degraded areas identified by the Forest Department should be rehabilitated and enriched by extensive habitat restoration programmes with native tree species, including important food items for gibbons;
5. Alternative and long-lasting poles for betel vineyards should be provided by NGOs and the Government of Bangladesh at reasonable prices to prevent over-harvesting of tree saplings from the forest. Extensive awareness programmes should be conducted to discourage the collection of forest wood for poles;
6. Proper use of alternative sources of fuel wood for refugees should be ensured and regularly provided by concerned authorities; and
7. General public education and awareness programs for different stakeholders should be implemented to help to manage the globally threatened wildlife habitat of Bangladesh on a larger scale.

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Assessment of changes over a decade in the patterns of livestock depredation by the Himalayan Brown Bear in Ladakh, India

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Abstract: Conflicts between large carnivores and shepherds constitute a major socio-ecological concern across the Himalaya and affects community attitudes and tolerance toward carnivores. We assessed the extent and intensity of Human-Brown Bear interactions in the same villages of Zanskar and Suru Valleys, Ladakh, in the Indian Trans-Himalaya during two time periods (2001–2003 and 2009–2012) through field and questionnaire surveys. During 2001–2003, 180 families of 32 villages in Zanskar, and 232 families of 49 villages in Suru were interviewed, and during 2009–2012, 145 families of 23 villages in Zanskar and 115 families of 33 villages in Suru were interviewed. Overall, 475 (119/year) and 454 (151/year) heads of livestock were reportedly killed by Brown Bears. The surveys of 2009–2012 revealed that livestock predation in 'doksas' (summer grazing camps) was higher (68 %) compared to the surveys carried out during 2001–2003 (42 %). The increased livestock depredation in doksas might be due to the extended stay and use of pastures by the local communities during spring and autumn. Damage to property in the form of breaking open of doors and windows by Brown Bear were reported during both the surveys. Economic losses and declining tolerance of people may trigger retaliatory killings of Brown Bear in Ladakh. We recommend compensation for livestock loss and improved husbandry practices in the conflict zones for bear-human coexistence.

Keywords: Conflict, Himalayan Brown Bear, Human-Brown Bear interactions, field and questionnaire surveys, Ladakh, livestock depredation, Suru, Trans-Himalaya, Zanskar.

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Author contributions: Initially SSK conceived the idea in early 2000s and carried our the fieldwork during 2001 to 2003. Later, AM followed the similar habitats and carried out the fieldwork and analysed the data during 2009 to 2012. AM, AAK and SSK wrote, reviewed and approved the article.

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INTRODUCTION

Worldwide, the Brown Bear *Ursus arctos* is the most widely distributed species among the eight species of bears (Servheen 1990; Schwartz et al. 2003; Nawaz 2007). They are distributed in most of the northern hemisphere, including the Palearctic and Nearctic regions of the world (Servheen 1990). They inhabit alpine and sub-alpine mountainous landscapes of Asia, Europe, and North America. Their numbers and distribution range have contracted by more than 50% in Asia during the past century (Servheen 1990). The Himalayan Brown Bear *U. a. isabellinus* (Image 1), a subspecies that represents an ancient lineage of the Brown Bear (Galbreath et al. 2007), has a restricted distribution in the Greater and Trans-Himalayan regions of Jammu & Kashmir, Ladakh, Himachal Pradesh, and Uttarakhand in India (Sathyakumar 2001, 2006). The Himalayan Brown Bear occurs in subalpine forests and alpine meadows in the Greater Himalaya of Jammu & Kashmir, Himachal Pradesh, and Uttarakhand, and in the cold-arid alpine scrub and meadows in the trans-Himalayan regions of Ladakh (Sathyakumar 2003, 2006). Sathyakumar (2001, 2006) reported, through questionnaire-based surveys, Brown Bears are present in 23 protected areas and 35 other localities throughout the northwestern and western Himalayan regions of India.

In the Himalayan landscapes, local communities generate their livelihoods largely through nomadic pastoralism, horticulture, subsistence farming, and eco-tourism activities (Jaypal 2000; Maheshwari et al. 2010; Maheshwari 2018; Maheshwari & Sathyakumar 2019, 2020); however, due to increase in livestock densities and consequent expansion of pastoralism into new areas that were historically natural and undisturbed habitats, domestic species (e.g., cattle such as cow, yak *Bos grunniens*, dzo-dzomo (yak-cow hybrids), sheep *Ovis aries*, goat *Capra aegagrus* and equids) are more vulnerable to predation by Himalayan Brown Bear, which may lead to retaliatory killing by local communities (Karimov et al. 2018; Maheshwari 2018; Dai et al. 2020). In India, Brown Bears are threatened due to poaching for bear parts and retaliatory killings to reduce livestock depredation (Sathyakumar 2001, 2006) and has significantly contributed to the local declines of the populations of Brown Bear and other large carnivores such as Snow Leopard *Panthera uncia* and Wolf *Canis lupus* in the Himalayan region (Jackson et al. 2001; Spearing 2002; Maheshwari et al. 2010; Can et al. 2014; Maheshwari 2016; Maheshwari 2018; Maheshwari & Sathyakumar 2019, 2020; Dai et al. 2020). Sound scientific research is necessary for making management decisions related to Brown Bears and for sustainable management of their populations (Servheen 1990; Sharief et al. 2020); however, there has not yet been detailed field research on the Himalayan Brown Bears in Ladakh.

Image 1. Brown Bear *Ursus arctos isabellinus* .

We conducted field and questionnaire surveys in Zanskar and Suru valleys of Ladakh, India, during two time periods, viz., 2001–2003 and 2009–2012 to understand the patterns of Human-Brown Bear interactions in order to plan effective conservation and management actions for Brown Bears and their co-existence with local communities.

MATERIALS AND METHODS

Study Area

The Zanskar and Suru valleys of Kargil District in the Union Territory of Ladakh (Figure 1) falls within the Trans-Himalayan biotic province (1B) of India (Rodgers et al. 2000). Topographically, the region is mountainous with vast valleys characterised by open and dry steppe vegetation indicating arid conditions. Major vegetation formations include open or desert steppe dominated by grasses, sedges, and dwarf shrubs such as *Ephedra gerardiana, Capparis spinosa, Salsola collina, Stipa klimesii, Leymus nutans, Eurotia ceratoides*, *Artemisia*

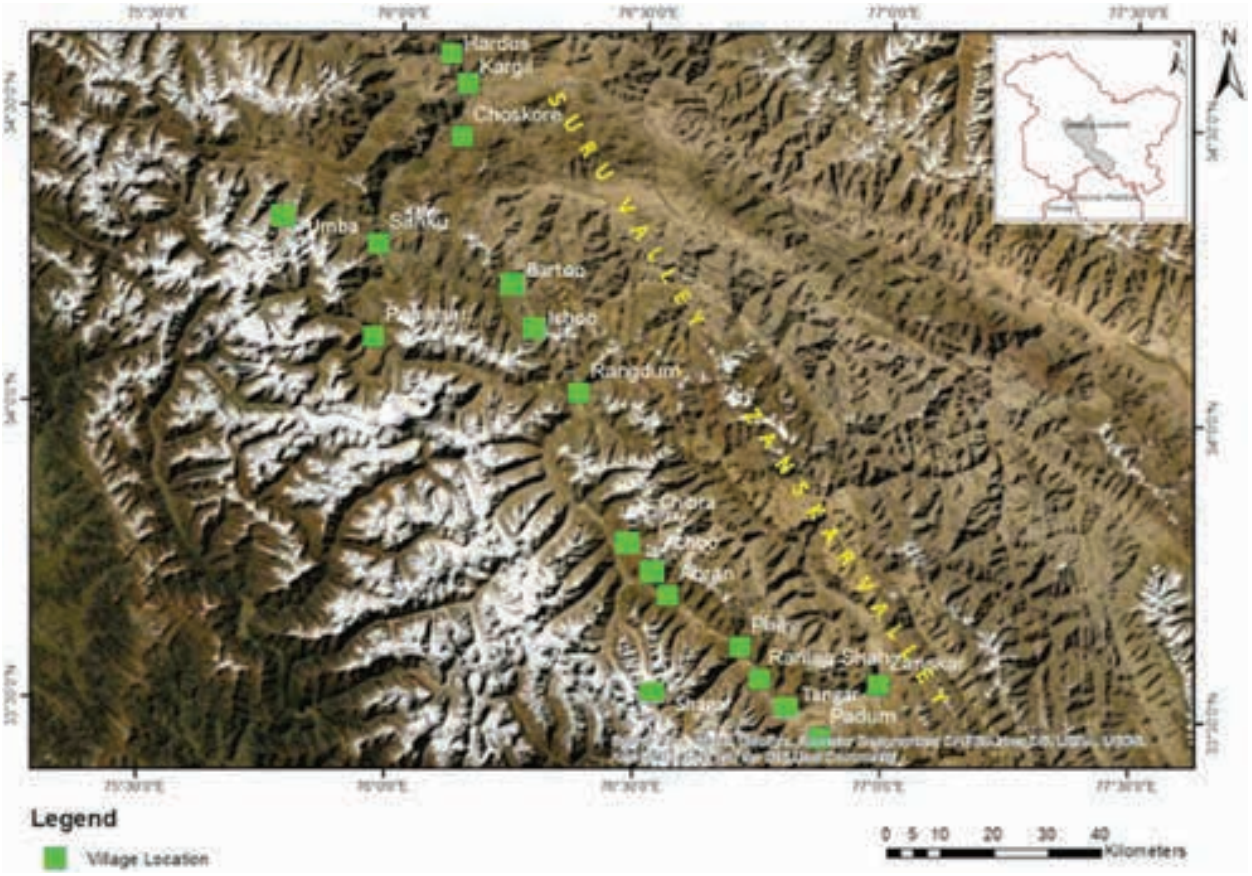

Figure 1. Map of the study area showing major villages interviewed to gather information on livestock depredation by Brown Bear in Kargil.

macrocephala, Hippophae rhamnoides, Myricaria elegans, and *Caragana species* (Kala 2011; Maheshwari 2016). Large mammals that co-exist with Brown Bears in the Kargil Himalaya include the Snow Leopard, Wolf, and Ibex *Capra ibex*. The elevation in the study area ranges 3,400–7,510 m with significant land surface under permafrost coverage (Maheshwari 2016). The climate in the study area is largely dry with extreme cold conditions throughout the region (Maheshwari 2016).

The Suru Valley forms a major portion (4,500 km^2) of Kargil District (Figure 1) and it is characterised by steep and rocky mountains, wide valleys with human habitations and agriculture/horticulture lands. Rivers Suru and Drass drain the valley which join the Indus flowing in the north (Maheshwari 2016). The Zanskar Valley (3,000 km^2) is the region located south of Pensi La (4,400 m) and it is characterised by large valleys with human habitations and agriculture/horticulture lands and surrounded by mountains. Zanskar River drains the valley and joins the Indus at Nimmo (Maheshwari 2016). The Zanskar Valley is bordered by the Great Himalayan high mountains to the south and west. Traditionally, the local communities are involved in subsistence agriculture and agro-pastoral based lifestyle, they cultivate the land along the course of the drainage system, wherever artificial irrigation from mountain streams is possible. Kargil is one of the sparsely populated regions in India and settlement pattern is just along the river valleys and a few broad valleys (Maheshwari 2016). The human population in the study area is dominated by Buddhists (in Zanskar Valley) and Muslims (in Suru Valley) with human density of 8 persons/km² for Kargil District (Census of India 2011).

Methods

Characterization of human-bear interaction: (a) semi-structured interviews.

We carried out field and questionnaire surveys for 75 days during the summer months of 2001 (40 days), 2002 (20 days) and 2003 (15 days) in Zanskar and Suru valleys to assess the extent and intensity of Brown Bear-Human interactions. The surveyed localities include most of the villages along the main Kargil-Padum motor road and in the side valleys of Sanku, Umba, Rangdum, and Padum that are representative of the Zanskar and Suru valleys. We repeated these surveys in the same

villages (as it was conducted during 2001–2003) during the summer months of 2009–2012 (90 field days). Informal semi-structured interviews (Sathyakumar 2001; Maheshwari et al. 2014; Dai et al. 2020) were used to collect information on livestock holdings and livestock depredations from the villagers.

We interviewed a minimum of five families in a village and if livestock depredations due to Brown Bear were reported by even one of these five families, then we sampled at least 30% of the total families living in that village (Sathyakumar 2003). Villagers living in doksa (seasonal nomadic settlement used by agro-pastoral communities to shelter their livestock during summer in the Greater and Trans-Himalaya of India; Maheshwari 2013) were also interviewed. To reduce and avoid overestimation of livestock depredation, we employed participatory rural appraisal (PRA), a standardised approach for collecting data on large carnivore-human interaction using the semi-structured interview technique of PRA (Maheshwari et al. 2014). We conducted informal meetings in public places (e.g., community centres) and personal visits to the villages, to explain study objectives to local communities. Meetings were open to all. We recorded people's complaints about wildlife damage, especially damage by Brown Bears. Following these meetings, a semi-structured questionnaire format was developed in line with preliminary interviews. Interviews were then carried out in all the villages, doksa and seasonal settlements that were known to experience frequent conflict incidents. Our sampling involved face-to-face interviews with villagers and reflected first-hand experience and knowledge. Moreover, through personal interaction, we believe it was generally possible to judge the authenticity of the claims or cross check them, thus improving overall reliability (Maheshwari et al. 2014).

Characterization of human-bear interactions: (b) field survey.

To understand the spatial distribution of livestock predation by Brown Bear, the GPS locations of the predation cases were recorded during the surveys and a kernel-density transformation were adopted to understand predation density across the study area. It provides a median to visualize point pattern to detect hotspots (O'Sullivan & Unwin 2003). Kernel-density estimation provides a map of estimates of local intensity of any spatial process from a set of observed occurrences (Bailey & Gatrell 1995). A development gradient representing the conflict intensities through varying densities of conflict was created (Worton 1989) using kernel-density tool in ArcGIS 10.5 (ESRI 2016). The method begins by centring a bivariate probability density function with unit volume (i.e., the 'kernel') over livestock predation locations. A regular grid is then superimposed on the data and a probability density estimate was calculated at each grid intersection by summing the overlapping volumes of the kernels. A bivariate kernel probability density estimator (i.e., a 'utilization distribution') was then calculated over the entire grid using the probability density estimates at each grid intersection (Kernohan et al. 2001). The resulting kernel probability density estimator would have relatively large values in areas with many observations and low values in areas with few. We calculated the distribution using the fixed kernel estimator with least squares cross validation (LSCV) as the smoothing parameter, with a sample size ≥30. This search radius (bandwidth) is computed specifically to the input dataset using a spatial variant of Silverman's rule of thumb that is robust to spatial outliers (Silverman 1986).

RESULTS

Interviews distribution

In total, 412 respondents from 81 villages were interviewed during the 2001–2003 survey. It comprised 180 respondents from 32 villages of Zanskar, and 232 respondents from 49 villages of Suru. Additionally, in Zanskar, 16 villagers living in eight doksas were also interviewed. Whereas, during second time survey (2009 –2012), 145 respondents representing 23 villages of Zanskar and 115 respondents from 33 villages of Suru Valley were interviewed and a total of 20 villagers in doksas were also interviewed in Zanskar Valley.

Livestock holding

The overall livestock population had increased by about 9% (from 2001 to 2010; Table 1) which was mostly due to increase in the numbers of cattle (18%), sheep and goats (10%), and the decline in the numbers of equids (7%). Further, shepherds reported a marginal shift in the increased use of high-altitude pastures (at doksa) during spring and autumn as compared to the 2001–2003 surveys.

Livestock predation by Brown Bear

Data from 2001 to 2003: The average livestock predation by brown bear was of 3.15 (29.05±1.65) animals per household (i.e., on average 151 livestock/ annum were reportedly killed by brown bear for those sampled families). Majority of the incidences took place

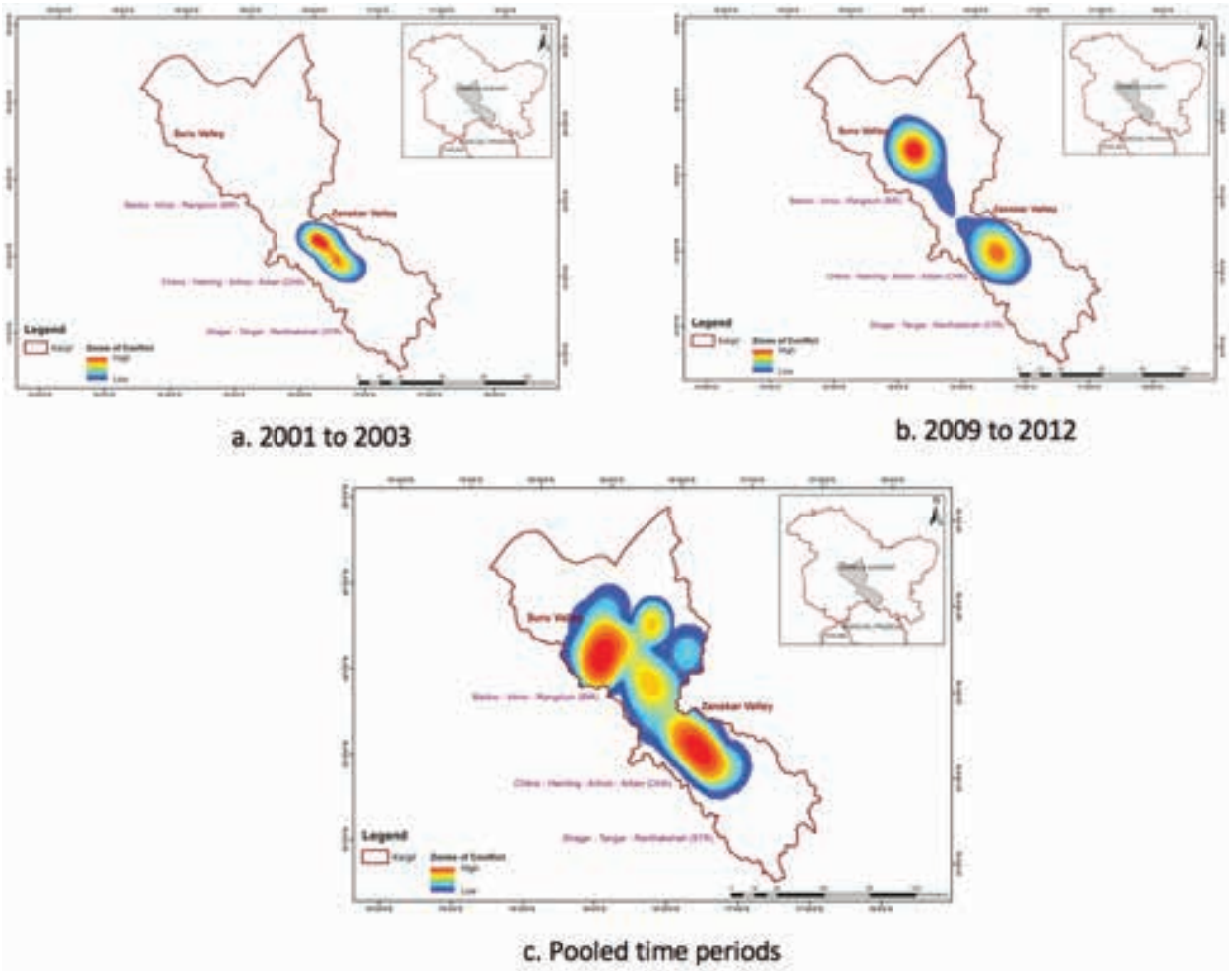

Figure 2. Map showing Brown Bear-Human interactions in Kargil through kernel distributions of the events of livestock depredation during 2001 to 2003 (a), 2009 to 2012 (b), and 2001 to 2012 (c).

Table 1. Livestock holdings in the Brown Bear habitats surveyed in Zanskar and Suru valleys during 2001 and 2010.

Number of families and their livestock details	2001		2010	
	Zanskar	Suru	Zanskar	Suru
No. of families surveyed	180	232	145	115
Cattle (cow, yak, dzo-dzomo)	1379	989	1651	1154
Sheep and goats	1489	1249	1628	1389
Equids (horses /mules/ donkeys)	834	747	849	619

Table 2. Comparison of livestock predation by brown bear at various sites in Ladakh during two time periods, 2001 to 2003 and 2009 to 2012. Key: BIR- Bartoo-Ichoo-Rangdum, STR- Shagar-Tangar-Ranthakshah, CHA- Chibra-Hamling-Achoo-Abran.

Livestock predation across sites	2001 to 2003	2009 to 2012
Doksas	200	309
Villages	257	145
Night shelter	19	-
Livestock predation conflict hotspots		
BIR	-	173
STR	208	281
CHA	267	-

in the villages (n= 257; 54 %) followed by doksa (n= 200; 42 %) and livestock night shelters (n= 19; 4 %) (Table 2). Brown Bears preyed mainly on young ones of cow, yak and dzo-dzomo (age= <1 year; n= 248; 52 %) and goat and sheep (n= 195; 41 %). Most of the depredations were reported during summer (n= 195; 63 %) and to some extent in spring (n= 87; 28 %). Locals reported visual encounters of Brown Bears on livestock kills (n= 153; 37 %) or have confirmed it based on tracks and signs (n= 259; 63 %) found near kills and their predation behaviour.

Data from 2009 to 2012: The average livestock predation was of 4.56 (44.34±2.65) animals per household (i.e., 119 livestock/annum were reportedly killed by brown bear for the sampled families). Majority of the incidences took place in doksas (n= 309; 68 %) followed by villages (n= 145; 32 %; Table 2). Brown Bears preyed mainly on sheep and goats (n= 245; 54 %) followed by young ones of cow, yak and dzo-dzomo (age= <1 year; n= 209; 46 %). Most of the depredations were reported during summer (n= 185; 66 %) and spring (n= 95; 34 %). Locals reported more frequent Brown Bear visual encounters on livestock kills in Zanskar Valley (n= 177; 68 %) than Suru Valley (n= 83; 32 %).

Spatial patterns in Brown Bear-Human conflicts:

Data from 2001 to 2003: In Zanskar, two conflict zones were identified (i.e., Shagar-Tangar-Ranthakshah areas (STR) and Chibra-Hamling-Achoo-Abran areas (CHA); Figure 1a). The Brown Bear was reported to have preyed upon 6.3 % (total livestock population 3,301 in sampled families) and 7.9 % (total livestock population 3,386 in sampled families) of the livestock population of CHA and STR, respectively (Table 2).

Data from 2009 to 2012: We recorded two-conflict zones viz., one in Suru (Bartoo-Ichoo-Rangdum; BIR) and another one in Zanskar (Shagar-Tangar-Ranthakshah; STR) (Figure 2b). The Brown Bears were reported to have preyed upon 5 % (total livestock population 3,450 in sampled villages) and 7.3 % (total livestock population 3,840 in sampled villages) of the livestock population of BIR and STR, respectively (Table 2).

Trend in Brown Bear-Human interactions

A kernel distribution of the events determined three interaction zones, viz., BIR, in Suru and CHA and STR in Zanskar Valleys in both the time periods (Figure 2c). During the period 2009 to 2012, the total livestock loss due to Brown Bears (including both valleys) was of 6.5 % (n= 7,290), of which Zanskar and Suru reported 6.9 % (n= 3,840) and 6.1 % (n= 3,450) livestock loss, respectively. Similarly, in 2001 to 2003, the total livestock loss due to Brown Bears (including both valleys), was of 6.8 % (n= 6,687), of this, Zanskar and Suru reported 6 % (n= 3,310) and 7.5 % (n= 3,386) of their livestock loss respectively.

DISCUSSION

Local communities were primarily concerned for the livestock depredation and damage to their properties by the Brown Bear in Zanskar and Suru valleys. Both led to economic losses in the local communities, and possibly therefore, retaliatory killing cannot be ruled out. Spearing (2002) reported that three Brown Bears were killed in Zanskar in retaliation during 1998–2001; however, we did not register any such case during the study duration. Retributory killing of Brown Bear have been reported from the neighbouring state of Himachal Pradesh, India in which the migratory shepherds (gaddis) often kill Brown Bears to reduce livestock predation (Sathyakumar 2001; Rathore & Chauhan 2007; Sharief et al. 2020). Rathore (2008) reported that livestock depredation by Brown Bear ranged from 2.2 % to 12.9 % livestock/annum in Kugti Wildlife Sanctuary, Himachal Pradesh, India. There had not been any cases of attacks on humans by Brown Bear in Himachal Pradesh (Rathore 2008); however, during the 2001–03 survey, first-hand accounts of Brown Bear attack on humans (in 2001) was recorded from a villager in Abran Village (Zanskar Valley; Sathyakumar 2003). In Sanjiangyuan of the Tibetan Plateau, the Tibetan Brown Bears *Ursus arctos pruinosus* were estimated to damage properties more significantly than livestock depredation (Dai et al. 2020). Whereas, in our findings there is a comparatively more loss (almost 132 heads of livestock annually) of livestock in Kargil. This disparity is explained by the poor guarding practices and unsupervised livestock grazing in the Indian Himalaya region (Rawat 2007; Maheshwari 2016). We observed that most people around Zanskar kept dogs to guard the livestock but efficiency of such measures was limited, which are widely used probably lead to habituation to brown bear (Sathyakumar 2001; Ambarlı & Bilgin 2008; Rathore 2008; Can et al. 2014; Maheshwari 2018).

Pattern of Brown Bear-Human interaction

We estimated a decline of 37 % (n= 152; from 2001–2003 to 2009–2012) in the number of respondents who reported cases of Brown Bear-Human interaction. Although there was an 18 % increase in the total number of livestock holdings by the respondents, the livestock loss to Brown Bear remained almost the same. The present study also made an attempt to understand the presence of Brown Bear with livestock predation caused by it in the conflict zones. During 2009–12, we recorded 88 evidences of Brown Bear with 6 % livestock loss in BIR and 31 evidences of Brown Bear with 9 % livestock loss in STR of the total livestock population in both the conflict zones. This high number of Brown Bear evidences and low levels of conflict may be due to improved livestock husbandry practices in BIR. Government owned livestock (sheep and goats) were not depredated by any wild carnivore as 5–6 staff members of the Sheep

Husbandry Department guarded the animals efficiently. Moreover, damage frequency seems to have increased in the summer pastures due to unsupervised grazing of the livestock, which in turn was caused by many residents either moving to big cities for better jobs or opportunities in the eco-tourism sector in Zanskar range.

CONCLUSION AND PERSPECTIVES

Livestock is one of the major sources of livelihood for the agro-pastoral communities in Kargil and Zanskar (Maheshwari 2016; Maheshwari & Sathyakumar 2020). Due to a lack of proper infrastructure and poor guarding practices, livestock is more exposed to Brown Bear depredation in Kargil and Zanskar. In addition, unsupervised grazing of cattle and horses in hill slopes or nullas (streams in narrow valleys) and sheep and goat grazing by children are two of the key contributing factors for Brown Bear depredation in Kargil and Zanksar Himalaya. We propose adoption of adult supervised livestock grazing at the village level and improved predator proof livestock corrals and night shelters for reducing Brown Bear depredations (Maheshwari & Sathyakumar 2020). Since the Brown Bear population is declining throughout most of its range in southern Asia, and their population is still small, the species have poor growth potential, and a relatively low genetic diversity (Nawaz 2007). It requires a continuous field and genetic monitoring. Maintaining and improving the connectivity with adjacent populations in Pakistan and India will be of utmost importance for its long-term survival. We also recommend payment of compassionate grants for livestock loss and improved husbandry practices in the interaction zones for bear-human coexistence.

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COMMUNICATION

Habitat selection of Himalayan Musk Deer *Moschus leucogaster* (Mammalia: Artiodactyla: Moschidae) with respect to biophysical attributes in Annapurna Conservation Area of Nepal

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Abstract: Himalayan or White-bellied Musk Deer *Moschus leucogaster*, an IUCN indexed endangered species, is distributed in isolated pockets in the Himalaya. The deer population is decreasing owing to several pressures that include habitat loss and fragmentation, and poaching. It is essential to identify preferred habitat characteristics to support appropriate management strategies for conserving this endangered species. This study was carried out in the Nysheang basin of Annapurna Conservation Area of Nepal to identify habitats preferred by the musk deer. Habitat field parameters were collected using transect surveys. To analyze vegetation use and availability, nested quadrate plots size 20 m^2 were established. Ivlev's electivity index (IV) (-1 to +1) was employed to determine habitat preference, and one-way ANOVA (F) and chi-square tests ($\chi 2$) were used to examine different habitat parameters. Similarly, the importance value index (IVI) of the vegetation was calculated. Our results showed that the Himalayan Musk Deer strongly preferred habitats at 3601–3800 m altitude (IV= 0.3, F= 4.58, P <0.05), with 21–30º slope (IV= 0.2, F= 4.14, P <0.05), 26–50 % crown cover (IV= 0.25, F= 4.45, P <0.05), 26–50 % ground cover (IV= 0.15, F= 4.13, P <0.05), and mixed forest (IV= 0.29, $\chi 2$= 28.82, df= 3, p <0.001). Among the trees, *Abies spectabilis* (IVI= 74.87, IV= 0.035) and *Rhododendron arboretum* (IVI= 55.41, IV= 0.02) were the most preferred, while *Rhododendron lepidotum*, *Cassiope fastigiata* (IV= 0.35) and *Berberis aristata* (IV= 0.25) were the most preferred shrubs, and *Primula denticulata* (IV= 0.87) and *Primula rotundifolia* (IV= 0.31) were the most preferred herbs. These preferred habitat conditions should be maintained and conserved to sustain a viable population of deer in the study area. Further studies will be required to assess the effects of climate change on habitat suitability.

Keywords: Climate change, conservation, habitat suitability, Nysheang Valley, White-bellied Musk Deer.

Nepali संक्षिप्त: हिमालयन अथवा ह्वाईट बिल्ड कस्तुरी मृग *Moschus leucogaster*, IUCN मा सुचित लापोन्मुख प्रजाति, हिमालिय क्षेत्रका विभिन्न ठाउँहरुमा अवस्थित छन् । यी मृग प्रजातिको संख्यामा कमी हुनुको मुख्य कारण वासस्थानको क्षेती र विखण्डनका साथै चोरी शिकारी हुन । यी लोपोन्मुख प्रजातिको संरक्षणका लागि उपयुक्त व्यवस्थापनको रणनितीहरु तय गर्न उनीहरुको प्राथमिकतामा पर्ने वासस्थानहरुको विशेषताहरु पहिचान आवश्यकता छ । यो अध्ययन नेपालको अन्नपूर्ण संरक्षण क्षेत्रको निस्याङ्ग भ्यालीमा कस्तुरी मृगले मन पराउने वासस्थानको पहिचान गर्न गरिएको थियो । यस अध्ययनका लागि ट्रान्जेट सर्भेक्षण प्रयोग गरि उनीहरुको वासस्थान क्षेत्रका प्यारामिटरहरु संकलन गरिएको थियो । वनस्पति प्रजातिहरुको प्रयोग र उपलब्धताको विश्लेषण गर्न २० वर्ग मिटर आकारको नेष्टेड क्वाडरेट प्लटहरु स्थापना गरिएको थियो । उनीहरुको वासस्थानको प्राथमिकताको निर्धारण गर्नका लागि Ivelv's electivity index (IV) (-1 to +1) प्रयोग गरिएको थियो भने विभिन्न वासस्थान प्यारामिटरहरुको परिक्षण गर्नका लागि वान वोय ANOVA (F) र chi-square tests ($\chi 2$) टेस्टहरु प्रयोग गरिएको थियो । त्यसै गरि वनस्पतिहरुको लागि Importance Value Index (IVI) निर्धारण गरिएको थियो । हाम्रो अध्ययनले हिमालयन कस्तुरी मृगले ३६०१-३८०० उचाई (IV= 0.3, F= 4.58, P <0.05), २१-३० डिग्री भिरालोपन (IV= 0.2, F= 4.14, P <0.05), २६-५० प्रतिशत क्राउन कभर (IV= 0.25, F= 4.45, P <0.05), २६-५० प्रतिशत ग्राउण्ड कभर (IV= 0.15, F= 4.13, P <0.05) र मिश्रित वन (IV= 0.29, $\chi 2$= 28.82, df= 3, p <0.001), रहेका वासस्थाहरुलाई निकै मन पराएको देखिन्छ । रुख प्रजातिहरुमा *Abies spectabilis* (IVI= 74.87, IV= 0.035) र *Rhododendron arboretum* (IVI= 55.41, IV= 0.02) धेरै मन पराईएका छन् भने झाडी प्रजातिहरुमा *Rhododendron lepidotum*, *Cassiope fastigiata* (IV= 0.35) र *Berberis aristata* (IV= 0.25) धेरै मन पराईएका छन् र भुई घाँस प्रजातिहरुमा *Primula denticulata* (IV= 0.87) र *Primula rotundifolia* (IV= 0.31) बढि मन पराईएका छन् । यस अध्ययन क्षेत्रका कस्तुरी मृगको स्वयंसमर्थता जनसंख्यालाई दिगो बनाउन उनीहरुको प्राथमिकतामा परेका वासस्थानहरुको अवस्थालाई कायम राख्न र संरक्षण गर्न आवश्यकता देखिन्छ । साथसाथै, उनीहरुको वासस्थान उपयुक्तामा जलवायु परिवर्तनका प्रभावहरुको आंकलन गर्न थप अध्ययन अनुसन्धान आवश्यक छ ।

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INTRODUCTION

Musk Deer under genus *Moschus* are of taxonomic, biological, and commercial interest; the latter primarily arising from the value of the musk produced by adult male deer (Khadka & James 2016). Refined and improved knowledge has enabled the recognition of seven *Moschus* species (Li et al. 2016), with three occurring in Nepal (Satyakumar et al. 2015): the Black Musk Deer *M. fuscus*, Alpine Musk Deer *M. chrysogaster* of the eastern Himalaya, and the Himalayan or White-bellied Musk Deer *M. leucogaster* of the central Himalaya. Based on the mtDNA analysis, Singh et al. (2019) validated that the southern parts of the Himalaya of Nepal, India, and Pakistan hold the ranges of two species, Himalayan Musk Deer and Kashmir Musk Deer *M. cupreus* of western Himalaya and Hindu Kush.

The National Parks and Wildlife Conservation Act, 2029 (1973), Nepal (GoN 1973) includes the Musk Deer *Moschus chrysogaster* (Image 1) in Schedule-1 as a "Protected Wildlife" species. Earlier, *M. chrysogaster* was believed to be the only Musk Deer species of Nepal. *M. fuscus* was believed to be extinct, or not recorded in Nepal (Bhuju et al. 2007, page 30, 106), and *M. leucogaster* was earlier treated as subspecies of *M. chrysogaster* (Satyakumar et al. 2015). In the present study, we have treated the Musk Deer of Annapurna Conservation Area as *Moschus leucogaster* (hereby Musk Deer) in central Nepal. The species is categorized as 'Endangered' in the IUCN Red List (Harris 2016).

The Musk Deer is a solidary and crepuscular mammal that is found at higher elevations from 2500 to 4500 m (Green 1986). The species inhabits in the mountain forest of China, northern India, Bhutan, and Nepal (Green 1986; Grubb 2005). It is confined in protected areas of high mountainous regions of Nepal, namely Api Nampa Conservation Area (ANCA), Khaptad National Park (KNP), Rara National Park (RNP), Shey Phoksundo National Park (SPNP), Sagarmatha National Park (SNP), Dhorpatan Hunting Reserve (DHR), Annapurna Conservation Area (ACA), Manaslu Conservation Area (MCA), Langtang National Park (LNP), Makalu Barun National Park (MBNP), and Kanchenjunga Conservation Area (KCA) (Jnawali et al. 2011; Aryal & Subedi 2011). Forests of oak, rhododendron, blue pine, juniper, and grasslands are the preferred habitat types of the Musk Deer (Green 1986; Kattel & Alldredge 1991).

Habitat preference is an intrinsic behavior that determines the selection and fitness of species to particular habitat (Jaenike & Holt 1991). It is an element of natural factors which may prompt to the improvement of asset choice behavior (Boyce & McDonald 1999; Manly et al. 2007). An asset choice may be forever or briefly exhausted by the action of the creature (Green 1986). Moreover, habitat preference is the disproportionality among utilization and accessibility (Manly et al. 2007). Creatures are liable to contending requests and inspirations for example, must secure nourishment, discover mates, raise offspring, protect restricted assets, and maintain a strategic distance from predators. So as to achieve these goals, their decision of natural surrounding selection is influenced and balanced over their area in space (Hebblewhite & Merrill 2009). The majority of the wildlife conservationists have concentrated on natural surrounding selection for managing the populaces and anticipating impacts of natural surrounding disturbances (Boroski et al. 1996). Other than this, however, it can be utilized as an apparatus to see how environment, behavior and wellness are connected (McLoughlin et al. 2008; Gaillard et al. 2010). The growing anthropogenic weight and their following impacts on natural life has been well seen all around (Millenium Ecosystem Assessment 2005).

Image 1. Musk Deer captured during fieldwork in Annapurna Conservation Area.

The population of Musk Deer is declining due to several anthropogenic pressures, including illegal hunting and habitat loss or degradation (Jnawali et al. 2011) due to human encroachment, firewood collection, etc. (Thapa et al. 2018). Suitable living space for deer is principally limited to protected areas in fragmented habitats (Singh et al. 2018a). As per Shrestha (2012), Musk Deer is one of the least studied mammals and its population is found in highly isolated areas. Hence taking all these considerations, our study was focused to identify and explore the state of the habitats in respect

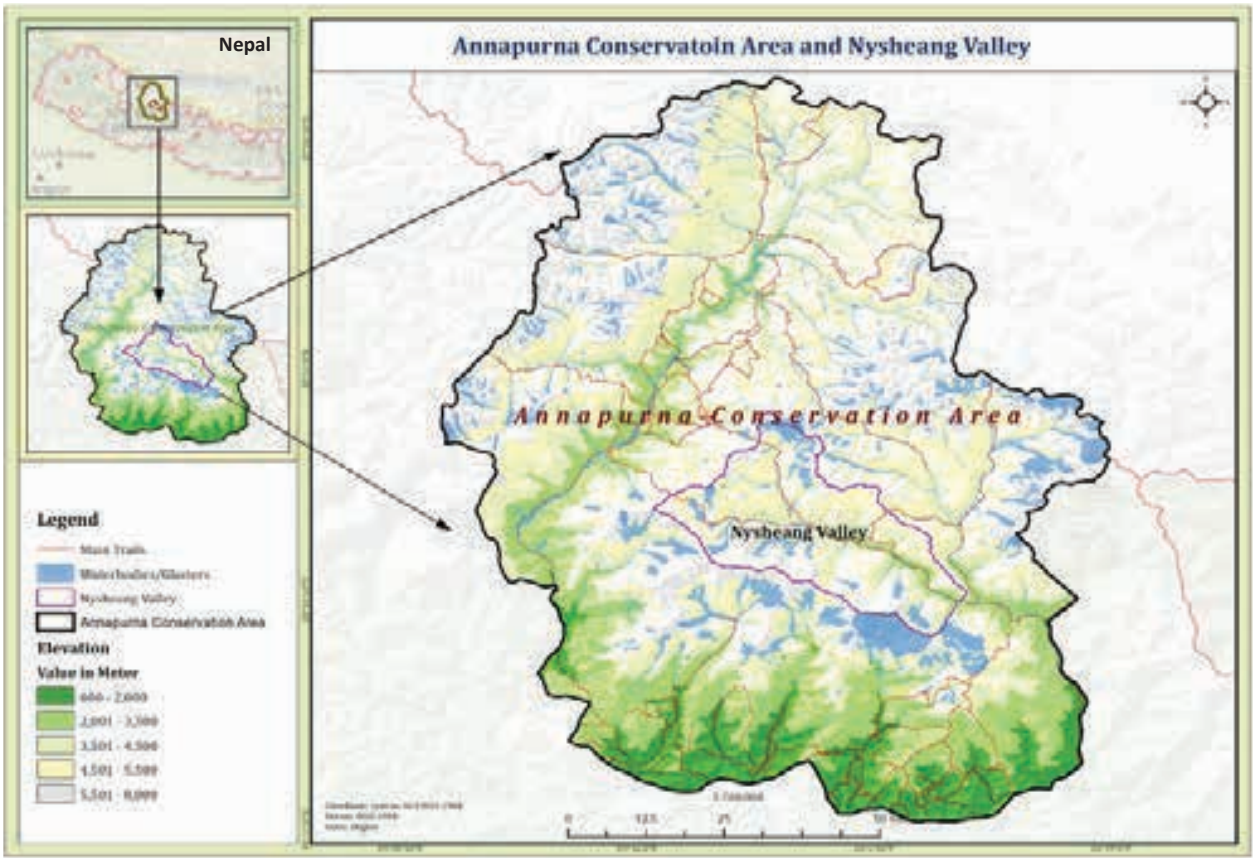

Figure 1. Location map of Annapurna Conservation Area and Nysheang Valley, Nepal.

of topographic and vegetation highlights that portray their habitat preferences.

MATERIALS AND METHODS

Study Area

The Annapurna Conservation Area (ACA) is located in the hills and mountain of west-central Nepal (28.231–29.336^{0}N and 83.486–84.445^{0}E) and covers a total area of 7,629 km^2 under five districts (DNPWC 2016). It is the first and largest conservation area of the country. To the north, it is bounded by the dry mountainous deserts of Dolpa and Tibet, toward the west by the Dhaulagiri Himal and the Kaligandaki Valley, toward the east by the Marshyangdi basin, and toward the south by the valleys and lower regions incorporating Pokhara. It harbors number of faunal species including 488 birds, 23 amphibians, 20 fish, 105 mammals, 40 reptiles and 347 butterflies (DNPWC 2016). ACA supports living space for several threatened mammal species including Himalayan Brown Bear *Ursus arctos*, Red Panda *Ailurus fulgens*, Common Goral *Nemorhardus goral*, Lynx *Felis lynx*, Himalayan Marmot *Marmota himalayana*, Red Fox Vulpes *vulpes*, and bird species including Danphe *Lophophorus impejanus*, Lammergier *Gypaetus barbatus*, Golden Eagle *Aquila chrysaetos*, Cheer Pheasant *Catreus wallichi*, Crimson-horned Pheasant *Tragopan satyra* (Inskipp & Inskipp 2001; DNPWC 2016). The Musk Deer mainly occurs in the valleys of Manang and Mustang districts of ACA. The Nysheang Valley of Manang (Figure 1), within the north-east portion of ACA is one of the major pocket areas for Musk Deer (Singh et al. 2018a). It occupies an area 689.6 km^2 and elevation ranging 2,900–7,939 m.

Data Collection

The study was conducted during March of 2018. At that time, the snowfall had decreased and the melting of snow had accelerated, which aided our investigation. To identify habitat parameters, a random sampling technique was utilized. Throughout the study area 'habitat use plots' (U) and availability plots (A) were adopted. On each location where indirect signs of Musk Deer such as latrine, hair, pugmark, and bed site were observed; 'habitat use plot' was established within 50 m

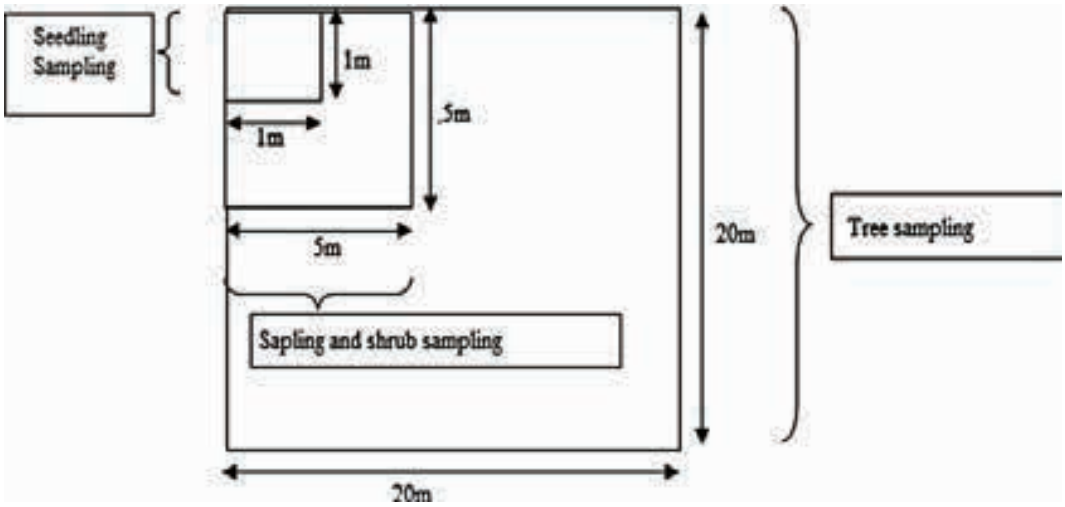

Figure 2. Layout of quadrats within the transect in the study area.

distance. Habitat parameters, in particular the gradient, altitude, crown cover, ground cover and land features were noted from each plot. 'Habitat availability plots' were chosen at 100 m distance from the use plots in a random direction (Panthi et al. 2012) and the similar habitat parameters were noted as recorded in the use plots. 'Availability plots' were renamed as 'use plots' if signs of the deer were present in availability plots. Vegetation analysis was performed within both the use and availability plots. Quadrats of size 20 × 20 m were placed on each transect at the intervals of 100 m (Singh et al. 2018a). Within the quadrats, nested structured small quadrats of size 5 × 5 m and 1 × 1 m were laid (Figure 2). Trees (dbh >10cm) were measured in each 20 × 20 m quadrat, shrubs and sapling (tree species >1 m height and <10 cm diameter) were measured in 5 × 5 m quadrats and seedlings (tree <1 m in height) were measured in 1 × 1 m quadrats and those measurements were recorded. Besides, information such as the tree diameter at breast height (DBH), height, crown cover, number of trees, ground cover, frequency of tree, shrub and herb as well as signs of animals were collected within the quadrats.

Data Analysis

Using Ivlev's electivity index (IV), habitat preference of deer was analyzed. The IV value ranges from -1.0 to + 1.0. Habitat preference is indicated by the positive value, whereas negative value indicates avoidance and finally, 0 values indicate random use (Ivlev 1964). For this purpose, following relation was used.

I or IV = (U%-A%) / (U%+A %) (Ivlev 1964; Krebs 1989; Panthi et al. 2012), where U and A refer to use and availability plots, respectively.

Regarding vegetation analysis, the field data was utilized to calculate the species richness, frequency and relative frequency, density, and relative density of tree using following formulae (Smith 1980).

Density of species

$$A = \frac{Total\ number\ of\ individuals\ of\ species\ A}{Total\ number\ of\ areas\ surveyed * Area\ of\ plot}$$

Relative density of species

$$\mathrm{A} = \frac{\text{Total number of individual of species A}}{\text{Total number of individuals of all species}}$$

Frequency of species

$$A = \frac{Number\ of\ plots\ in\ which\ species\ A\ occurs * 100}{Total\ number\ of\ sample\ plots}$$

Relative Frequency of species

$$A = \frac{Frequency\ value\ of\ species\ A * 100}{Total\ frequency\ values\ of\ all\ species}$$

Relative dominance of species

$$A = \frac{Total\ basal\ area\ of\ species\ A * 100}{Total\ basal\ area\ of\ all\ species}$$

Importance value index (IVI) was calculated as

IVI = Relative density + relative frequency + relative dominance.

Besides, one-way ANOVA and Chi-square test were used to identify the significances of different habitat variables; crown cover, ground cover, forest types with respect to Musk Deer presence at 5% level of significance.

RESULTS

Habitat Preferences

Altitude Preference: The Musk Deer mainly preferred altitudinal ranges of 3,601–3,800 m with (IV= 0.3) (Figure 3). Altitudinal preference increased from 3201 m to 3800 m in a gradual manner. The altitudinal range of 3,801–4,000 m (IV= 0.2) was least preferred. Similarly, the region beneath the elevation 3,200 m (IV= -0.25) and above 4,000 m (IV= -0.8) was avoided. The utilization of different altitude intervals in extent to their availabilities was statistically significant (F= 4.58, P <0.05).

Slope Preference: Primarily, the Musk Deer preferred the slope 21º to 30º (IV= 0.2) (Figure 4). Preference slope expanded in continuous way from 11º to 30º and somewhat diminished up to 40º. It avoided the slope <10º (IV= -0.25) and >40º (IV= -0.71). The use of different slopes in extent to their availability was statistically significant (F= 4.14, P <0.05).

Crown Cover Preference: Mainly, the Musk Deer favored the crown cover of 26 to 50 % (IV= 0.25) followed by crown cover of 51 to 75 % (IV= 0.05), while 76 to 100 % (IV= -0.65) crown cover was evaded (Figure 5). The utilization of different crown cover in extent to their availability was statistically significant (F= 4.45, P <0.05).

Ground Cover Preference: Initially ground cover was partitioned in 4 classes for the analysis. Ground cover having 26–50 % (IV= 0.15) and 0–25% (IV= 0.09) was mostly preferred by Musk Deer while it completely avoided 76–100 % cover (IV = -0.75) (Figure 6). This suggests that it preferred scarce and modest ground cover. The use of different ground cover in extent to their availability was statistically significant (F= 4.13, P <0.05).

Since most of pellet was documented in forest, it was figured out that the Musk Deer preferred forest (IV= 0.15) (Figure 7). The cliff (IV= 0) and rock (IV= 0) were utilized randomly and the stream-bed (IV= -0.43) was totally dodged. The use of different ground features in extent to their availability was statistically significant (F= 3.29, P <0.05).

Forest Types Preference: The proportion of forest types utilized by the Musk Deer was statistically significant ($\chi 2$= 28.82, df= 3, p <0.001). From Figure 8, it can be concluded that mixed forest (IV= 0.29) was

Table 1. Affiliation of different biophysical variables with the living space of Musk Deer in the study area.

Variables	Estimate	SE	Z-value	P-value
(Intercept)	-5.36	2.36	-2.27	<0.05
Betula forest	1.44	1.67	0.85	0.39
Mixed forest	5.06	2.09	2.41	<0.05
Rhododendron forest	1.73	1.63	1.05	0.28
Distance to settlements	0.002	0.001	1.53	0.012
Rock cover	0.02	0.01	1.71	0.08
Litter cover	-0.14	0.06	-2.20	<0.05

SE—Standard error.

Table 2. Musk Deer presence and the occurrence of different tree species in the study area.

	Species	Relative Density	Relative Dominance	Relative Frequency	IVI	Ivlev's Value	Status
1.	*Abies spectablis*	21.46	32.25	21.16	74.87	0.035	Prefer
2.	*Rhododendron arboretum*	16.34	23.73	15.34	55.41	0.02	Prefer
3.	*Betula utilis*	13.66	5.3	11.82	30.78	0.01	Prefer
4.	*Rhododendron campanulate*	13.9	19.55	13.4	46.85	0.034	Prefer
5.	*Spruce* spp	7.56	2.5	7.58	17.64	0.16	Prefer
6.	*Taxus bacata*	5.61	4.04	6	15.65	0.15	Prefer
7.	*Cupresus* spp	5.85	2.1	5.82	13.77	- 0.36	Avoid
8.	*Abies pindrow*	4.15	1.56	4.76	10.47	0.14	Prefer
9.	*Berberis* spp	3.9	3.6	3.88	11.38	0.135	Prefer
10.	*Honey suckle*	1.71	0.98	2.65	5.34	0.12	Prefer
11.	*Pinus wallichiana*	2.2	0.62	3	5.82	-0.4	Avoid
12.	*Sorbus lanata*	0.73	1.22	1.59	3.54	-0.5	Avoid
13.	*Rododendron anthopogan*	1.46	1.19	1.41	4.06	0.12	Prefer
14.	*Acer* spp	0.98	0.88	0.88	2.74	0.15	Prefer
15	*Sorbus sapling*	0.49	0.48	0.71	1.68	0.12	Prefer
	Total	**100**	**100**	**100**	**300**		

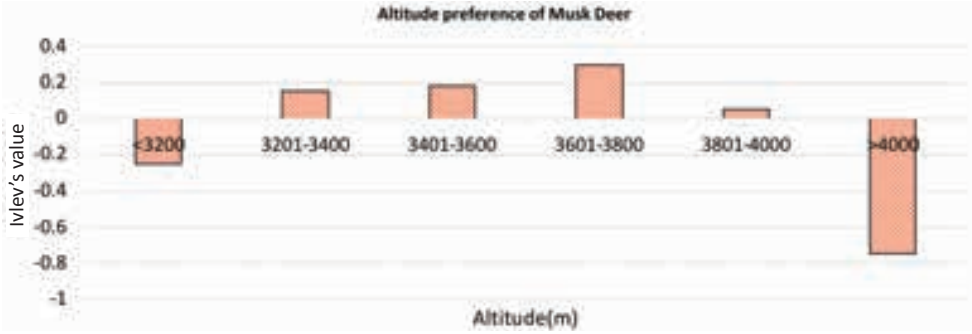

Figure 3. Preferred altitude by Musk Deer in the study area.

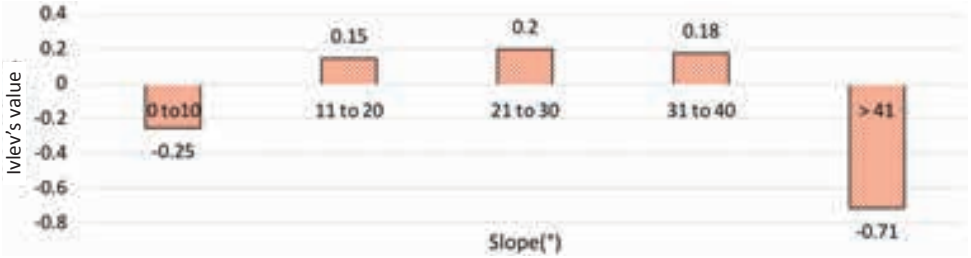

Figure 4. Preferred slope by Musk Deer in the study area.

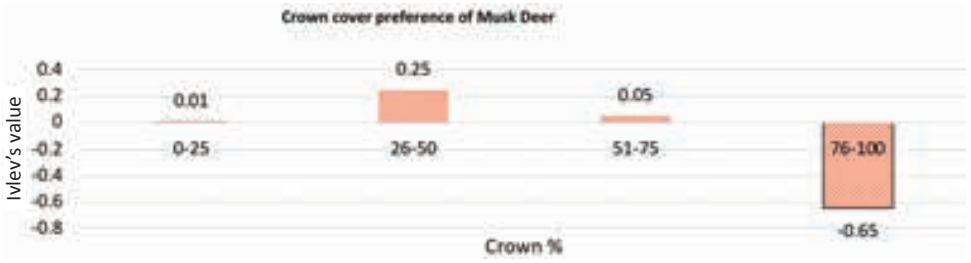

Figure 5. Preferred crown cover by Musk Deer in the study area.

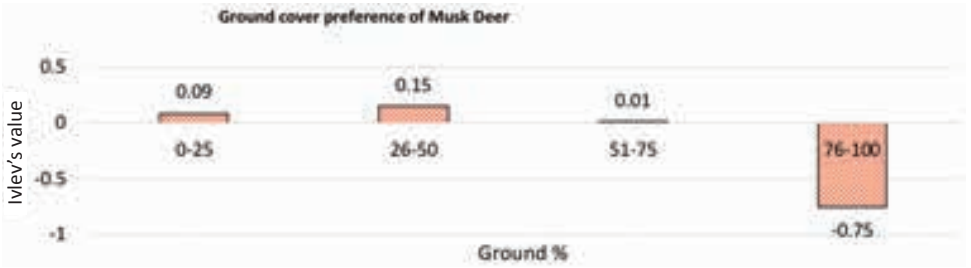

Figure 6. Preferred ground cover by Musk Deer in the study area.

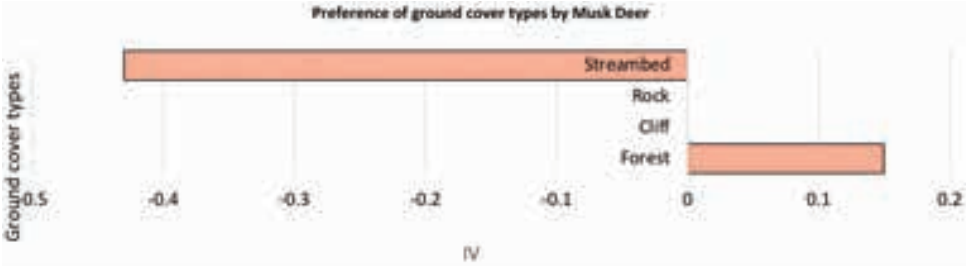

Figure 7. Ground cover types preferred by Musk Deer in the study area.

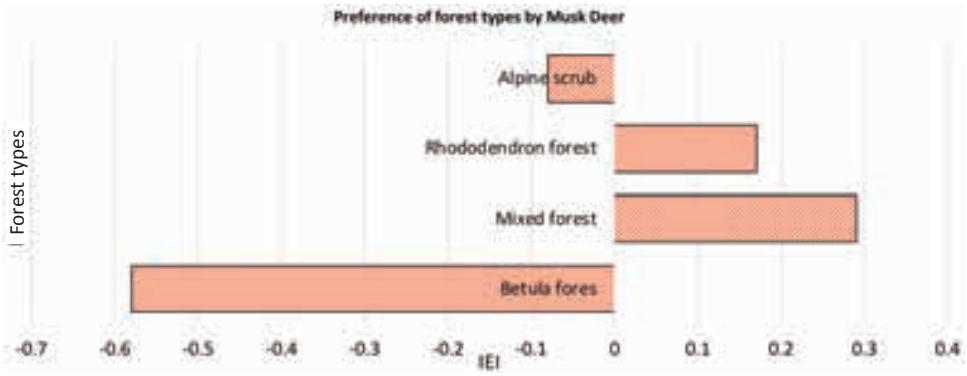

Figure 8. Forest types preferred by Musk Deer in the study area.

mostly preferred, and the second preference was for *Rhododendron* forest (IV= 0.17), whereas, *Betula* forest (IV= -0.58) along with alpine scrub (IV= -0.08) were completely avoided by the Musk Deer.

Influencing Biophysical Variables: Habitat sorts, fuel wood and wood cutting, rock cover, litter cover and distance to settlements influenced on the choice of the living space of the Musk Deer where mixed forest, distance to settlements and litter cover were the foremost and critical influencing factors (Table 1).

Tree Species Preference: Altogether 15 species of trees were recorded from 72 plots. Out of 15 tree species, the Musk Deer showed preference for 12 species and avoidance for 3 species (Table 2). Tree species that appeared to have been avoided include *Pinus wallichiana* (IVI= 5.82, IV= -0.4), *Cupresus* spp. (IVI= 13.77, IV= -0.36) and *Sorbus slanata* (IVI= 3.54, IV= -0.5).

Shrub Species Preference: A sum of 10 shrub species was documented within the 72 plots. The Musk Deer preferred *Rhododendron lepidotum* (IV= 0.35), *Cassiope fastigiata* (IV= 0.35), *Berberis aristata* (IV= 0.25), and *Rhododendron anthopogon* (IV= 0.02). Whereas, *Juniperus squamata* (IV= -0.15), *Incarvillea arguta* and *Rhododendron cillatum* (IV= -0.14) and *Caragana gerardiana* (IV= -0.34) were avoided (Table 3).

Herb Species Preference: Out of total 18 herb species documented, the Musk Deer favored nine species and avoided the remaining nine species. *Primula denticulata* (IV= 0.87), and *Primula rotundifolia, Primula sikkimensis, Bistorta macrophylla, Anaphalis triplinervis, Viola biflora, Primula gembeliana, Potentilla cuneata* and *Artemisia dubia* were in the preferred herbaceous habitat. Whereas, *Rumex nepalensis* and *Saussurea deltoidea* (IV= -0.35) were the most avoided herb species, and *Anemone demissa, Thalictrum alpinum, Aster albescens, Pedicularis poluninii, Morina nepalensis*, and *Meconopsis horridula* were in the area avoided by the Musk Deer (Table 4).

Table 3. Musk Deer presence and the occurrence of different shrub species in the study area.

	Species	Ivlev's value	Status
1	*Rhododendron lepidotum*	0.35	Prefer
2	*Cassiope fastigiata*	0.35	Prefer
3	*Berberis aristata*	0.25	Prefer
4	*Rhododendron anthopogon*	0.02	Prefer
6	*Incarvillea argute*	-0.14	Avoid
7	*Rhododendron ciliatum*	-0.14	Avoid
8	*Juniperus squamata*	-0.15	Avoid
9	*Rosa sericea*	-0.29	Avoid
10	*Caragana gerardiana*	-0.34	Avoid

DISCUSSION

Habitat usage relies upon factors like the creature's behavior, length of the day and the time of year in relation to accessibility of food, shelter, and cover (Green & Kattel 1997). Anthropogenic and natural factors may also influence accessibility to habitats and modify habitat preference (Pulliam & Daielson 1991). It is also possible that preferences vary among species of the same genus. In this context, without attempting to specify species level differences, we observed that our base-line findings (Table 1) on habitat preference by Musk Deer from ACA are comparable to certain extents with other studies in Nepal and neighborhood.

Khadka & James (2016) found that Musk Deer preferred small patch of pine and fir forest in the central Himalayas. While in ACA the preferences were the maximum in mixed forest to the minimum in Betula forest, and the preference for Rhododendron forest was low, close to that of Betula forest. The preference for

Table 4. Musk Deer presence and the occurrence of different herb species in the study area.

	Species	Ivlev's Value	Status
1	*Primula denticulate*	0.87	Prefer
2	*Primula rotundifolia*	0.31	Prefer
3	*Primula sikkimensis*	0.2	Prefer
4	*Bistorta macrophylla*	0.16	Prefer
5	*Anaphalis triplinervis*	0.15	Prefer
6	*Viola biflora*	0.14	Prefer
7	*Primula gembeliana*	0.12	Prefer
8	*Potentilla cuneate*	0.04	Prefer
9	*Artemisia dubia*	0.02	Prefer
10	*Anemone demissa*	-0.11	Avoid
11	*Thalictrum alpinum*	-0.13	Avoid
12	*Aster albescens*	-0.15	Avoid
13	*Pedicularis poluninii*	-0.16	Avoid
14	*Morina nepalensis*	-0.16	Avoid
15	*Meconopsis horridula*	-0.2	Avoid
16	*Oxytropis microphylla*	-0.34	Avoid
17	*Saussurea deltoidea*	-0.35	Avoid
18	*Rumex nepalensis*	-0.35	Avoid

forests of mixed stands and Rhododendron in our study appears similar to the findings by Shrestha & Meng (2014) in Gaurishankar Conservation Area, Nepal.

Concerning preferences for altitude range, Timmins & Duckworth (2015) suggested that 2,500–4,800 m is the most preferred for *M. leucogaster*, while Thapa et al. (2019) mentioned that 3,700–3,800 m was the foremost favored altitudinal extent for *Moschus* in Khaptad National Park, Nepal. Ilyas (2015) observed that a majority of the latrines of *M. chrysogaster* in Uttarakhand Himalaya, India occurred from 4,200 m down to 2,500 m. A study carried out by Srivastava & Kumar (2018) revealed that Musk Deer preferred the habitat within the altitude range 3,600–3,900 m in Sikkim Himalaya. Likewise, the Musk Deer highly preferred that altitude range 3,600–3,900 m in Api-Nampa Conservation Area, Nepal (ANCA 2018). In our study, the species favored the altitudes of 3,600–3,800 m, which is similar to the altitudinal preference in Api-Nampa Conservation Area, Nepal and Himalaya of Sikkim. However, elevation alone does not directly affect the Musk Deer's distribution. Instead, elevation is correlated with other climatic predictors like precipitation, temperature and solar radiations (Elith & Leathwick 2009) that lead to the change in habitat features and its quality to support the occurrence of the species.

In Api-Nampa Conservation Area, the slopes of 21–30º are highly preferred followed by slopes >40º by Musk Deer and avoid the slope of 0–10º (ANCA 2018). The study carried by Singh et al. (2018b) recorded the majority of latrines of Musk Deer in the slope of 20–40º in ACA. Our study in ACA coincides with these two studies as the principally preferred slope lie at 20–30º and completely avoid the slopes of 0–10º and >41º. Plain slope in our study was avoided due to presence of cattle grazing. Shrestha (2012) also suggested that Musk Deer avoid areas with high human disturbances like fuel wood collection and cattle grazing. And the slope >41º might have been avoided because of difficult terrain that resist them escaping from their predator.

Study carried out by Singh et al. (2018b) reported that Musk Deer prefer greater crown cover with high shrub diversity. In contrast to this, Musk Deer preferred moderate crown cover, i.e., 26–50 % in Api-Nampa Conservation Area (ANCA 2018), which is similar to our study. This is because the dense cover suppresses the growth of the ground level vegetation due to low light penetration, which might create the food shortage for the Musk Deer. This insight is supported by the study of Awasti et al. (2003) who recognized Musk Deer as the mixed feeder, i.e., grazers and browsers.

The thickness of ground cover governs the habitat preference of Musk Deer. The study carried out by Ilyas (2015) stated that Musk Deer prefer sparse ground cover. This study is supported by the study carried out in Api-Nampa Conservation Area where Musk Deer principally prefer the ground cover of 26–50 % (ANCA 2018), which is similar to our study in ACA. The dense ground cover is avoided; the reason could be that it is less friendly since it resists the rapid movement of Musk Deer that hinders to escape from predator. Singh et al. (2018b) reported that 69 % of the Musk Deer latrines were observed under tree, 26.4 % under canopy, and 4.6 % under rock. Similar to this study, forest and cave were found to be preferred and stream bed was found to be avoided in our study, which may be because the forest and caves are used for thermal requirements and escape whereas the streams are difficult to move across.

According to Khadka & James (2016), the Himalayan Musk Deer seems to utilize the region featured by presence of *Pinus* species and *Abies* species forest with moderately thick canopy cover (26–50 %) on higher elevation zone (≥ 3600 m) of the northern aspect. These choices are apparently social and structural adjustments (Futuyma & Moreno 1988). Musk Deer are shy and elusive creatures (Kattel 1993) with longer rear appendages compared to forelimbs, an adaptation for

living in rough terrain at high elevations. The domination of *Abies* species, which have dense crown cover, protects the area from snow, while the rivers flowing through the area serve as major water sources for Musk Deer throughout the year.

Data on habitat parameters and their levels of preference recorded from different protected areas provide valuable baseline data, and offer the scope for determining micro-habitat for different species of *Moschus* in Nepal. Correlations in future when camera traps or molecular studies enable to have clear knowledge on the profile of species in each protected area.

CONCLUSION

The Musk Deer appear to have habitually utilized mixed and Rhododendron stands for defecation and foraging. Deer occurrence is sparse at lower elevations and higher elevations close to the tree line, and they are mostly distributed between 3,600 and 4,000 m. Thus altitudinal ranges of 3,800–4,000 m with mixed and Rhododendron woods adjacent to water sources are appropriate regions to execute conservation programs to protect Musk Deer and their environment. The likelihood of pellet presence diminished with the rise in ground elevation. A total of 15, 10 and 18 species of tree, shrub and herb were recorded, respectively, in the study area. The occurrence of Musk Deer was more around the forested area with crown cover of 26–50 %, and the tree species Abies *spectablis*, *Betula utilis, Acer spp.*, *Rododendron spp.*, *Spruce spp., Taxus bacata, Honey suckle, Berberis spp.* etc. The terrain with *Pinus wallichiana*, *Cupresus spp.* and *Sorbus spp.* appear to have been avoided. Likewise, the deer appear to have preferred areas where we have listed four species of shrub and nine species of herb, and further studies are required to assess the habitat suitability of the Musk Deer in response to climate change.

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COMMUNICATION

Sero-diagnosis of tuberculosis in elephants in Maharashtra, India

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Abstract: Tuberculosis is a highly contagious zoonotic disease caused by *Mycobacterium* spp. A study was conducted to detect the presence of *Mycobacterium* in captive elephants. A total of 15 captive elephants were screened from various regions in Maharashtra. The blood and serum samples collected were subjected to rapid test kit, BacT/ALERT 3D system, Ziehl-Neelsen (ZN) staining and PCR. All the samples were found seronegative using rapid test kit and whole blood PCR. Whereas, all samples were signalled culture positive in BacT/ALERT 3D system which were further subjected to PCR, only one amplicon was produced of 176bp of RD4 gene (*Mycobacterium bovis*) and no acid-fast organism was detected upon ZN. Due to the atypical nature of this organism, diagnosis of this disease in elephants using various tests is complicated unlike the diagnostic tests that are validated in domestic animals. Therefore, many tests have sub-optimal sensitivity and specificity in elephants. As TB is a zoonotic disease, transmission can occur between human-livestock-elephants interface. Therefore, the zoos and state forest authority should inculcate a protocol of periodic TB screening for Mahouts and elephants in captivity along with protocol of elephant-visitor interaction, thus helping in conservation of this endangered species in India.

Keywords: Elephants, mycobacterium, serodiagnosis, Tuberculosis.

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INTRODUCTION

Elephants are the largest terrestrial mammals on the earth. Elephants belong to the family Elephantidae in animal kingdom. Two genera *Elephas* and *Loxodonta* and three species are present today – the Asian Elephant *Elephas maximus*, the African Bush Elephant *Loxodonta africana*, and the African Forest Elephant *Loxodonta cyclotis*.

Currently, a population of 27,312 elephants has been estimated from 23 states in India (Project Elephant Division, Government of India, 2017). In past decades, the population of elephants has drastically been reduced and since 1986, the Asian Elephant has been listed as 'Endangered' species on the IUCN Red List, as the wild population has declined by at least 50% (Choudhury et al. 2008). The Asian Elephant is placed in Schedule I and Part I of Indian Wildlife Protection Act (1972); conferring it the highest level of protection.

Tuberculosis is a highly contagious zoonotic disease in animals as well as humans. It is caused by highly pathogenic bacteria of *Mycobacterium tuberculosis* complex (MTBC) which are *M. tuberculosis, M. bovis*, and *M. canetti*. The *M. tuberculosis* and *M. bovis* are most pathogenic. Tuberculosis (TB) in elephants was first observed more than 2,000 years ago by ancient Ayurvedic physicians in Ceylon (Iyer 1937; McGaughey 1961). Transmission between human and captive animals has occurred following close and frequent contact (Kathleen et al. 2002). More frequent reporting of this disease occurs in Asian Elephants than in African Elephants may be due to closer human contact related to their use for performances, rides and in temple rituals. *Mycobacterium tuberculosis* is the predominating disease-causing agent in elephants, although TB cases have been caused by *M. bovis* (Mikota 2008). The reservoirs for *M. tuberculosis* and *M. bovis* are infected human and cattle (Hirsch 2004).

Elephants with tuberculosis infection show clinical signs like weight loss, wasting and weakness, coughing or dyspnoea have been reported but appear to be uncommon. Exercise intolerance may be observed in working elephants (Mikota 2008). In some cases, ventral oedema has been reported, but other pathologic factors could be the initiating cause (Seneviratna et al. 1966). Majority of times elephants infected with TB do not have any clinical signs. In some cases, elephants manifest symptoms only in advance stage of disease or may not be diagnosed until necropsy (Paudel & Tsubota 2016).

The study presents the clinical, serological, and culture data from 15 elephants present in captivity thus helping to diagnose and decrease TB risk to these wild animals.

MATERIALS AND METHODS

Study animals and sample collection

Blood and serum samples were collected from the 15 elephants in captivity of Forest Camp areas of Gadchiroli (19.4290° N, 80.0563° E), Pune Zoo (18.452^{0}N, 73.865^{0}E), Mumbai Zoo (18.978^{0}N, 72.835^{0}E), Shegaon temple (20.789^{0}N, 76.701^{0}E) in Maharashtra. The elephants were included in the study irrespective of their health status, age, sex or habitat.

Serological testing

The Wild TB alert kit is a lateral flow chromatographic immunoassay for the detection of antibodies of mycobacterium tuberculosis complex antigenserum, plasma and whole blood of elephants. This kit contents a unique cocktail of tuberculosis specific recombinant proteins (ESAT-6, CFP-10, MPB83, MPB70) and crude protein impregnated on nitrocellulose membrane housed in a disposable plastic cassette. After adding sample to the well followed by addition of diluent they travel through the membrane by capillary action. If antibodies are present, they bind to the antigen and a red colour band is observed in test area.

BacT/ALERT 3D system

BacT/ALERT 3D system is an automated microbial detection system which offers microbiological culture of blood. This mycobacteria detection systems utilize a colorimetric sensor and reflected light to monitor the presence and production of carbon dioxide (CO_2) dissolved in the culture medium. BacT/ALERT MB are disposable culture bottles with a removable closure contain 10 ml of media and an internal sensor that detects carbon dioxide as an indicator of microbial growth. The media formulation consists of: Middlebrook 7H9 Broth (0.47% w/v), Pancreatic Digest of Casein (0.1% w/v), Bovine Serum Albumin (1.0% w/v), Catalyse (48 µ/ml), in purified water. Bottle reflectance is monitored and recorded by the instrument every 10 minutes. The growth curve enters lag phase then the bottle is flagged positive. At the time of detection, approximate colony forming units (CFUs) are 106–107 per ml.

Ziehl-Neelsen/Acid Fast staining

Bacterial culture smear was prepared from samples indicated positive in BacT/ALERT 3D system on clean

and grease free slide, using standard protocol of Ziehl-Neelsen staining kit (Hi-Media Pvt. Ltd, India).

PCR detection of mycobacterium

DNA was extracted from blood samples and samples signaled positive in BacT/ALERT 3D system of 15 elephants using the extraction protocol described by Samrook et al. 1989 and Tissue Genomic DNA Extraction Mini Kit (FAVORGEN Biotech Corp, Taiwan). The extracted DNA was subjected to PCR by using the standard primer RD4 F 5'-AATGGTTTGGTCATGACGCCTTC-3'; R 5'-CCCGTAGCGTTACTGAGAAATTGC-3' and RD1 F 5'-CCCTTTCTCGTGTTTATAGTTTGA-3' R 5'-GCCATATCGTCCGGAGCTT-3' which was amplified 176 and 110 bp of *Mycobacterium tuberculosis* and *Mycobacterium bovis*. The PCR reaction was carried out at 94°C for 10 minutes followed by 35 cycles of denaturation at 94°C for 1 minute, annealing at 60°C for 30 seconds and extension at 72°C for 1 minute, with final extension at 72°C for 10 minutes. The PCR products were analysed by electrophoresis in 1.5% agarose gel at100 V for 45 minutes and documented. Amplicon of size 176bp and 110bp is specific for Mycobacterium genus.

RESULTS

The Table 1 shows the results of various diagnostic tests used for diagnosis of mycobacterium in elephants. The serum samples collected from the 15 elephants were seronegative by the rapid test kit as no coloured band was observed in the test area of the rapid test kit (Image 1). All the 15 samples were detected positive by the BacT/ALERT 3D system in 6 mean days. These samples were further subjected to ZN staining, no sample detected the presence of acid fast bacilli (Amer et al. 2016; Bapat et al. 2017) (Image 2). Isolates of DNA extracted from the blood samples of these 15 elephants were subjected to PCR which did not produce specific amplicon of 176bp and 110bp RD4 and RD1 gene. Similarly, the DNA isolates from the BacT/ALERT culture system did not produce amplicon of 176 and 110 bp but one isolate produced amplicon of 176bp of RD4 of targeted gene indicating presence of *Mycobacterium bovis* (BCG) (Bapat et al. 2017) as illustrated in Image 3 and 4.

DISCUSSION

Tuberculosis is a highly contagious zoonotic disease with high incidence and prevalence in human, domestic and wild animals of developing countries. Tuberculosis infection in captive elephants is ongoing and complex problem with respect to their conservation. Due to atypical nature of the mycobacteria that causes diseases, the diagnosis is rather complicated, apart from the fact that many diagnostic tests are developed for domestic species however, those are not validated for wild animals. Therefore, many tests have sub-optimal specificity and sensitivity.

Table 1. Overall results of test applied (n= 15).

Elephant No.	BacT/ALERT	ZN Staining	Blood PCR	BacT/ALERT + ve PCR	Rapid test
(E1)	Positive	Negative	Negative	Negative	Negative
(E2)	Positive	Negative	Negative	Negative	Negative
(E3)	Positive	Negative	Negative	Negative	Negative
(E4)	Positive	Negative	Negative	Negative	Negative
(E5)	Positive	Negative	Negative	Negative	Negative
(E6)	Positive	Negative	Negative	Negative	Negative
(E7)	Positive	Negative	Negative	Negative	Negative
(E8)	Positive	Negative	Negative	**Positive**	Negative
(E9)	Positive	Negative	Negative	Negative	Negative
(E10)	Positive	Negative	Negative	Negative	Negative
(E11)	Positive	Negative	Negative	Negative	Negative
(E12)	Positive	Negative	Negative	Negative	Negative
(E13)	Positive	Negative	Negative	Negative	Negative
(E14)	Positive	Negative	Negative	Negative	Negative
(E15)	Positive	Negative	Negative	Negative	Negative

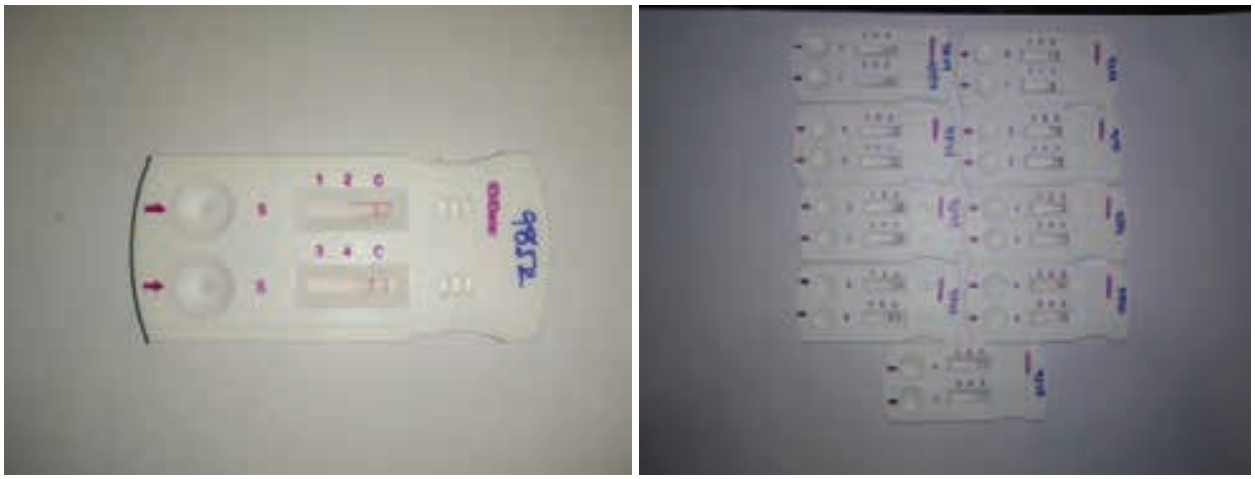

Image 1. Results of rapid TB test kit in elephants screened for tuberculosis.

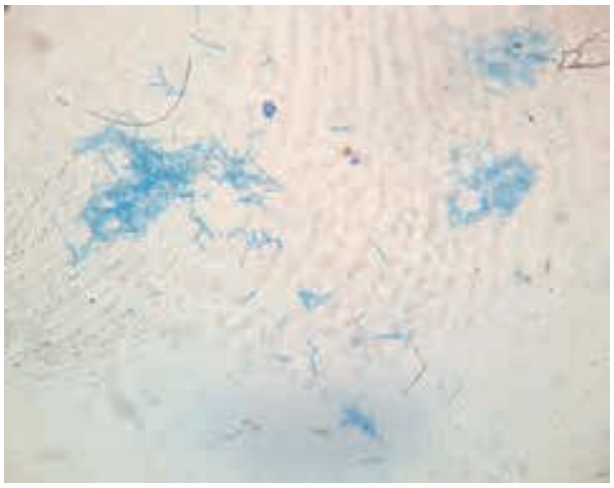

Image 2. Non-acid fast bacilli under microscope (100x) in elephants screened for tuberculosis.

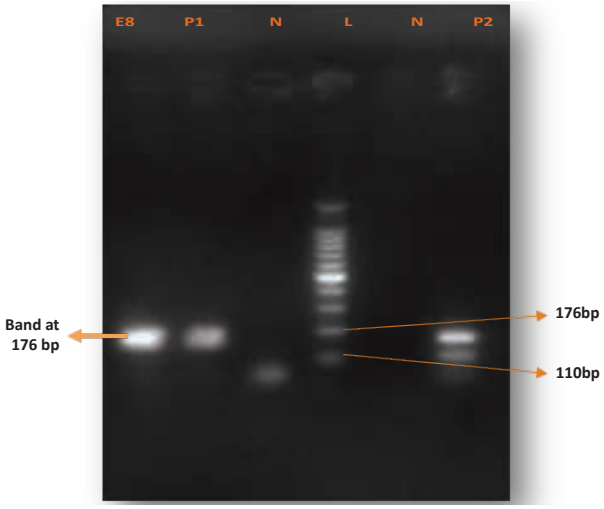

Image 3. PCR pattern of RD4 and RD1 gene at 176bp and 110bp of BacT/ALERT tuberculosis positive sample.
Lane E8: positive sample showing band at 176bp of RD4 gene, Lane P1: positive control (*M. bovis*), Lane P2: Postive control (*M. tuberculosis & M. bovis*), Lane N: negative control, Lane L: DNA ladder 100 bp.

The major problem to designate a perfect test among available tests for diagnosis of tuberculosis, which are most accurate for elephants, giving veterinarians a standardized method, which will allow them to make preventive measures and treatment protocols; thus, helping in conservation of endangered species like elephant.

These samples were subjected to diagnostic tests like BacT/ALERT 3D system, ZN staining, PCR, Rapid TB test kit. All 15 samples were signalled positive by BacT/ALERT 3D system. This test is not yet used and validated in animals, like in humans. This was the first time when the test was used in detection of TB in wild animals. Therefore, the specificity still remains a question. On the other hand, other tests like ZN staining, Rapid TB test kit and blood PCR did not detect any mycobacteria in the samples.

Molecular detection (duplex PCR) of the samples that signalled positive in BacT/ALERT 3D system was carried out using RD4 and RD1 gene primer with amplicon size of 176bp and 110bp respectively as described by Bapat et al. (2017). Only one sample was positive detecting the presence of *M. bovis* (BCG) at 176bp of RD4 gene.

During the study it was not possible to calculate the specificity of various diagnostic tests used. Development and use of new and more species specific diagnostic methods are needed at the moment, as it will help in early and accurate diagnosis that might permit early application of preventive measures and will ensure

Image 4. PCR pattern of RD4 and RD1 gene at 176bp and 110bp of blood samples
Lane E1-15: negative elephant DNA isolates, Lane P: Positive control (*M. tuberculosis* & *M. bovis*), Lane N: negative control, Lane L: DNA ladder 100bp.

Specimen/DNA Museum Information:
Specimen: Blood.
Museum: Niche Area of Excellence, Centre for Zoonoses, Indian Council of Agriculture Research (Central India), Nagpur Veterinary College, Nagpur.
Voucher Number: NAE9299.

safety of endangered species as well as human staff involved. Moreover, this mycobacterial disease requires long term surveillance plans in order to be effective, as this organism has prolonged incubation and latency.

Although, the reported case of TB in elephant in present study was caused by *M. bovis* (BCG) which is vaccine strain, its species predilection is still unidentified. Moreover, this animal should be screened multiple times over the period of time to confirm the disease. Cultural isolation of mycobacterium is currently the only gold standard test for TB diagnosis in elephants, but ancillary tests like PCR, BacT/Alert 3D system, rapid TB test kit etc. may be useful. The molecular method (PCR) used in diagnosis of mycobacterium in present study is not a confirmatory test due to its possibility of cross contamination (false positive) and inability to determine the pathogenicity of the organism. As this is a zoonotic disease, transmission of TB can occur between humans, livestock and elephants. Elephants are at risk of contracting TB from infected human (Mahouts). Therefore, Mahouts (handlers) and elephants should undergo periodic TB screening to minimize the risk of animals' health. Zoos and forest elephant camp areas should be encouraged to incorporate protocol for elephant-visitor interactions and periodic screening of animals for tuberculosis.

This study highlights the potential usefulness and efficacy of ante-mortem diagnostic methods. Use of multiple tests helps to achieve high possibility (sensitivity) of tuberculosis detection in elephants rather than using single test; however, it is important to evaluate and validate the test regime and will require addition of more animals in to the study; expectantly allowing in better understanding of tuberculosis in elephants, thus contributing to undertake control measures by state forest department and zoo authorities for conservation of this endangered species.

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Avian species richness in traditional rice ecosystems: a case study from upper Myanmar

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Abstract: Rice *Oryza sativa* ecosystems provide foraging and nesting habitat for a variety of birds. Myanmar is a major rice-producing nation and yet bird use of rice ecosystems remains largely unstudied. We present the results of a case study of avian species richness in a traditional rice ecosystem at Limpha Village in upper Myanmar. The rice field at Limpha occupies 17.5 ha where a single crop is produced each year without chemical inputs (fertilizer and pesticides). Village lands are contiguous with the buffer zone of Htamanthi Wildlife Sanctuary. We conducted bird surveys of the rice field during dry and wet seasons (2013–20) and documented the occurrence of 85 species (exclusive of Buttonquail these included 58 resident species, 20 migratory species, six species with both resident and migratory populations in upper Myanmar), including 10 species of conservation concern. Species richness was greatest during the dry season when an influx of Palearctic migrants was present. We ranked 52 species as Common, 23 as Uncommon, and 10 as Rare. Most birds used the rice field as foraging rather than breeding habitat. Insectivore was the most common feeding guild (43 species), followed by Omnivore (22 species), Carnivore (12 species), Granivore (6 species), Frugivore (1 species), and Nectarivore (1 species) guilds. We observed eight species associated with domestic Water Buffalo *Bubalus bubalis* and 15 species foraging at active fires or in burned areas in the rice field. Piles of rice straw are important foraging sites for several species. Low intensity agricultural practices, habitat heterogeneity, and proximity to the nearby swamp, forest, & Chindwin River are probably responsible for the relatively high avian species richness at Limpha. Future agricultural intensification could negatively impact avian species richness in the Limpha rice field. Our findings suggest that traditional rice agriculture is compatible with conservation objectives in the buffer zone of Htamanthi Wildlife Sanctuary. Our study, however, requires replication before generalizations can be made concerning the value of traditional rice ecosystems to avian conservation in Myanmar.

Keywords: Bird conservation, bird diversity, buffer zone, Chindwin River, Htamanthi Wildlife Sanctuary, *Oryza sativa*, rice field, Sagaing Region, traditional agriculture, water buffalo.

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For **Author details, Author contributions** & **Myanmar abstract** see end of this article.

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INTRODUCTION

Land devoted to the production of food, fiber, plant oils, and other resources used by human society occupies a substantial and increasing proportion of terrestrial biomes around the world (Bennett et al. 2006). As the extent of anthropogenically-modified landscapes expands to meet the needs of a growing human population, the fate of global biodiversity will increasingly depend on the quality and characteristics of farming landscapes (Pimental et al. 1992; Pino et al. 2000; Perfecto et al. 2009; Friskhoff et al. 2014). Farmlands vary widely in their ability to support biodiversity with some species being lost from agricultural landscapes, while other species persist and can even proliferate (Friskhoff et al. 2014). Despite the species loss that accompanies the conversion of wildlands to farmland (Rutt et al. 2019), a growing body of literature suggests that agricultural landscapes can make substantial contributions to global biodiversity conservation (Pimental et al. 1992; Jackson & Jackson 2002; Perfecto et al. 2009; Van der Weijden 2010).

Rice *Oryza sativa* is one of the most important food crops in the world (Forěs & Comín 1992; Bambaradeniya & Amarasinghe 2003). Rice is the primary source of nutrition for over half of the global human population and constitutes one-fifth of the world's grain supply (Elphick 2010). Rice is grown in at least 114 countries, rice ecosystems occupy >156 million ha of land (Elphick 2010), and more land is devoted to rice than any other agricultural crop (Forěs & Comín 1992). Because most rice is grown under flooded conditions (Lawler 2001), rice ecosystems are in effect, agronomically-managed freshwater marshes supporting a single species of cultivated grass (Bambaradeniya & Amarasinghe 2003). As managed wetlands, rice ecosystems constitute important habitat for a diverse array of wetland plants, invertebrates, and vertebrates (Lawler 2001; Czech & Parsons 2002; Bambaradeniya & Amarasinghe 2003; Halwart 2006; Elphick 2010). Among vertebrates, rice ecosystems are notable for providing foraging and nesting habitat for a wide variety of birds (Remsen et al. 1991; Dhindsa & Saini 1994; Hohman et al. 1994; Czech & Parsons 2002; Elphick 2010), including locally rare and globally imperiled species (Van der Weijden 2010). Furthermore, in some areas, (particularly in Asia) waterbirds have come to rely on rice ecosystems owing to the widespread loss of natural wetlands (Fasola & Ruiz 1996; Czech & Parsons 2002; Elphick 2010). Indeed, rice fields are often the best remaining wetland habitat for birds in many regions of the world (Fasola & Ruiz 1996; Elphick 2010; Fujioka et al. 2010).

Despite the acknowledged importance of rice ecosystems to avian conservation (Round 2002; Amano 2009; Van der Weijden 2010), bird use of this habitat outside of North America and Europe remains understudied (Czech & Parsons 2002; Elphick 2010). This is especially true in Asia where 90 % of the global rice crop is produced (Lawler 2001; Czech & Parsons 2002), and yet information on bird use of rice ecosystems remains surprisingly sparse (Duckworth 2007; Amano 2009; Fujioka et al. 2010; Sundar & Subramanya 2010). This situation is lamentable given the potentially high conservation value of rice ecosystems (Hohman et al. 1994; Amano 2009), coupled with the need to craft biologically-based management strategies that can maintain avian diversity without compromising agricultural production objectives (Van der Weijden 2010; Kumar & Sahu 2020). Furthermore, an enhanced understanding of avian ecology in rice ecosystems is critical for predicting the impacts of agricultural intensification likely to accompany the rapid economic development now occurring in much of southeastern Asia (e.g., Rao et al. 2013; Clements et al. 2014; Bhagwat et al. 2017).

Myanmar is one of the largest rice-producing nations in the world (GRiSP 2013), and rice production generates direct or indirect livelihoods for >75 % of the population (Naing et al. 2008). Rice is grown on 8 million ha of farmland with annual production amounting to >30 million tons (GRiSP 2013). Major rice-growing areas of Myanmar include the Ayeyarwady Delta, with significant production also occurring in the lowlands of Mandalay, Sagaing, and Magway Regions (Hla Myo Thwe et al. 2019). Rice was traditionally a monsoon crop until the 1970–80s when high-yielding varieties were introduced by the Myanmar government that allow double-cropping, i.e., cultivation of a crop during both the wet and dry seasons, with the dry season crop dependent on adequate irrigation (Naing et al. 2008; GRiSP 2013). Rice is typically grown on small farms (averaging 2.3 ha) by resource-poor farmers or landless agricultural laborers (Naing et al. 2008)

Despite the large amount of land devoted to rice production and the importance of this crop to the agricultural sector, other than passing mention of rice fields in scattered sources (Smythies 1953; Thet Zaw Naing et al. 2017) virtually nothing is known about bird use of rice ecosystems in Myanmar. We here present a case of study of avian species richness in a traditional rice ecosystem of upper Myanmar. In this study, we follow Bambaradeniya & Amarasinghe (2003) and define

a traditional rice ecosystem as a sustainable agricultural system dedicated primarily to the production of rice (and occasionally other crops such as fish) that employs minimal mechanization and few if any chemical inputs. Traditional rice ecosystems are generally assumed to support higher levels of biodiversity than modern intensive systems of cultivation, although little empirical data exist (Wood et al. 2010). Our objective was to determine what species of birds are seasonally present in a traditional rice ecosystem in upper Myanmar and their respective habitat use. To our knowledge, this is the only study (but see also Suarez-Rubio et al. 2016) that highlights the importance of rice ecosystems to birds in Myanmar.

Study Area and Overview of Rice Cultivation

Our study was conducted at Limpha Village (25.805N & 95.528E; elevation= 132m) in Sagaing Region (formerly Division) of northwestern Myanmar. This region experiences a tropical monsoonal climate with a wet season extending from early June through mid-October (mean annual rainfall varies from 1,250 to 2,500 mm depending on elevation), followed by a dry season from late October through May (Terra 1944). High diurnal temperatures (to 43 °C maximum) are typical of the dry season with low nocturnal temperatures (to 4 °C minimum) occurring in the winter months (January and February) (Terra 1944). Limpha is located within the Western Ornithological Region of Myanmar as defined by King et al. (1975).

Limpha is situated on the east bank of the Chindwin River approximately 40 km downstream from the regional administrative center of Khamti (Image 1). Limpha is the site of the Wildlife Conservation Society/ Turtle Survival Alliance River Turtle Conservation Project, hence our long-term (since 2008) institutional presence in the village (Platt & Platt 2019). The village consists of 34 occupied houses with an estimated population of 129 adults (≥18 years-old), most of whom are ethnic Shan. Subsistence agriculture supplemented by fishing and collection of non-timber forest products are the principal livelihoods, with many adult males employed as laborers in distant amber, jade, and gold mines. The origin of the rice ecosystem at Limpha is obscured by time; the rice field has been in existence for as long as the oldest residents (>80 years-old) of the community can remember. With the exception of the rice field (see below), the lands surrounding Limpha support dense tropical evergreen and semi-evergreen forest (Platt et al. 2013). Village lands are contiguous with the buffer zone that surrounds Htamanthi Wildlife Sanctuary (2,151 km^2).

The rice field is located adjacent to the village and occupies 17.5 ha of a terraced natural levee along the Chindwin River (Image 2a,b). The highest elevation in the rice field is along the natural levee (elevation ca. 134 m). The rice field slopes downwards, away from the river, and into a seasonally flooded swamp (elevation ca. 128 m) comprising about 5 ha that is filled by backwater flooding when river levels rise early in the wet season (July and August) and usually has dried completely by late March. Maximum water depth (ca. 2.0 m) in the swamp occurs in August and September. Soils under rice cultivation range from light silt-sand at the natural levee crest to heavy clay near the swamp. Much of the rice field is subdivided by low berms (20–30 cm high) into smaller square and rectangular-shaped paddies (mean ±1SD= 110.2 ± 46.2 m^2; range= 9.9 to 286 m^2) allotted to individual families for cultivation (Image 2b). Unlike more extensive rice ecosystems in central and southern Myanmar, the rice field at Limpha contains no irrigation ditches. A hedgerow (0.9 km) along the natural levee crest separates the rice field from the bed of the Chindwin River (Image 2c). The hedgerow is characterized by large clumps of bamboo, small to medium-stature trees, and thickets of the invasive perennial weed *Chromolaena odorata* (L.) King & H.E. Robbins, and serves as a source of construction materials (e.g., bamboo and timber) for the village.

Rice cultivation in Limpha is a subsistence activity to produce grain for domestic consumption, and little if any of the crop is sold. Rice is cultivated only during the wet season with a single crop being produced each year. Planting coincides with the onset of the wet season and generally begins in the last week of June or first two weeks of July, depending on rainfall. Tillage is accomplished with either wooden plows drawn by Water Buffalo *Bubalus bubalis* (Linnaeus, 1758) and Zebu Cattle *Bos taurus indicus* Linnaeus, 1758 or hand tractors; the latter came into use only in 2014 and four are now available in the village. Hand tractors are leased out by the hour with users responsible for the purchase of fuel. Rice seedlings are germinated in specially prepared beds in the village and then hand-planted into the field after the paddy substrate has been prepared by plowing (Image 3a). Planting is a communal activity with villagers reciprocally assisting one another as paddies are made ready to receive seedlings (Image 3b,c). Water for irrigation is supplied solely by rainfall and usually remains on the crop through the wet season. As defined by Khush (1984), the rice field at Limpha is a "rain-fed rice ecosystem"; i.e., lowland rice ecosystem dependent on rainfall, with water depth uncontrolled but usually

Image 1. Map of our study area showing Limpha Village, rice field, and Chindwin River. Inset shows the location of our study area (yellow star) within Myanmar. Ayeyarwady River= Red. Chindwin River= Blue.

shallow (1–50 cm).

Catastrophic crop failure is rare at Limpha but has occurred in the past when heavy rains in the headwaters caused prolonged overbank flooding of the Chindwin River. Herbicide and pesticide use is minimal to non-existent because villagers lack capital to purchase agrochemicals. Dung deposited by free-ranging domestic ungulates (Water Buffalo and Cattle) that graze the fallow rice field provides some fertilization. The rice crop is manually harvested during late October and early November. Hand threshing takes place at several locations scattered around the rice field. Like planting, harvesting is a reciprocal communal activity (Image 4). Although record keeping is minimal, villagers stated that annual rice yields can vary greatly, but average 900–1,000 kg/ha. Piles of rice straw are left at the threshing site and often (but not always) burned during the dry season. Rice straw is occasionally used as fodder for Water Buffalo. Rice stubble remains in the paddies to be plowed under during the next growing season.

Rice is cultivated in about 50 % of the paddies every year, with the remainder being left fallow for varying periods. Fallow paddies support grasses and sedges, various herbaceous weeds, scattered perennial shrubs, and thickets of *C. odorata*. Berms of active and fallow paddies support stands of high (2–3 m) grass. A herd of 20–25 Water Buffalo and two domestic cattle are kept by villagers; domestic ungulates serve as draft animals, provide fertilizer, and represent a capital investment that can be quickly converted to cash if the need arises. During the fallow season (October or early November through June) domestic ungulates graze in rice paddies, the adjacent swamp, and surrounding forest (Image 5a). At this time, ungulates are unrestrained and roam freely during the day, but are domiciled in the village at night to prevent the animals from straying into the forest and becoming feral. To protect the rice crop during the growing season, ungulates are tethered in

areas of favorable grazing and returned to the village in the evening. Owners are financially responsible for any inadvertent damage wrought to the rice crop by their livestock.

Grazing and trampling by free-ranging domestic ungulates creates "lawns" (sensu Owen-Smith 1987) of closely cropped grass in fallow paddies and around the periphery of the rice field (Image 5b). Water Buffalo also create wallows in fallow paddies that are in effect, small ephemeral waterholes. Wallows generally contain water throughout the wet season but are dry by early December and remain so until the rains begin in June (Image 5c). The rice field is burned during the dry season to kill encroaching vegetation (particularly *C. odorata*) and stimulate the growth of new grass for grazing ungulates (Image 5d). Burning usually begins in March and continues through the dry season and seems to be a haphazard activity with fires being opportunistically ignited when weather conditions are favorable. The resulting conflagrations are low intensity ground fires that often burn for >24 hours and ultimately create a patchwork of burned and unburned vegetation. The system of rice cultivation and domestic ungulate husbandry that we describe here appears typical of other villages along the Chindwin River, including those within the buffer zone of Htamanthi Wildlife Sanctuary.

METHODS

We made preliminary observations of birds in the rice ecosystem at Limpha during our initial, brief, and sporadic visits to the village during February–March of 2013–15. Our preliminary observations were followed by more intensive surveys conducted during February–March 2016–20, October–November 2017, and July–September 2020 when the bulk of fieldwork was completed. On most days we searched for birds during the morning (0730–1100 h) and afternoon (1600–1800 h), although sampling during parts of the wet season was less frequent owing to heavy rainfall and occasional flooding. When searching for birds, we used footpaths that originate in the village and radiate throughout the rice field as sampling transects. These footpaths run atop paddy berms and alongside the hedgerow and forest edge (Image 2c). The complete study area was accessible during the dry season, although flooding occasionally precluded access to some areas during the wet season. We also recorded birds opportunistically encountered in the rice field during the course of other fieldwork (e.g., Platt et al. 2018; Platt & Duckworth 2019). We identified birds with the aid of binoculars (Zeiss® and Nikon® 8 × 42) and occasionally by vocalizations. Our observations were augmented by two motion-sensitive game cameras (Moultrie® Series A programmed to take three photographs at 1-minute intervals), each mounted on a wooden post (approximately 0.5 m above-ground) and positioned near piles of discarded straw at two threshing areas in the rice field. Both game cameras were continuously operational from 10 February through 31 March 2019 (98 camera-trap days).

We classified the different habitats where birds were observed in the rice field as (1) rice paddy (paddies under rice cultivation or where rice was cultivated within past 12 months), (2) grass (fallow rice paddies and field margins now supporting primarily grasses), and (3) hedgerow. We included birds that were observed aerially foraging above the study area (e.g., swifts, swallows, and martins), but not high-flying raptors; however, raptors perched in the hedgerow or in trees around the field periphery, and low-flying birds obviously searching for prey were considered to be using the rice field. We used a modification of methods outlined by Kumar & Sahu (2020) to rank each species according to relative abundance as Common (60–100 % of field visits), Uncommon (20–59 % of field visits), and Rare (<20 % of field visits). We followed Sundar & Subramanya (2010) and classified birds according to feeding guilds as Carnivore (consume mainly non-insect invertebrates and vertebrates), Frugivore (consume primarily fruits), Granivore (consume seeds), Herbivore (consume mainly plants and plant parts), Insectivore (consume mostly insects), Omnivore (consume animals and plant material), and Nectarivore (consume mainly nectar). We used information provided in Smythies (1953), Robson (2008), Ali & Ripley (1989), Sundar & Subramanya (2010), and Birds of the World (www.birdsoftheworld.org), supplemented by our personal observations to assign each species to a particular foraging guild. We determined whether a species was resident or migratory in the study area based on Smythies (1953), Robson (2008), Birds of the World (www.birdsoftheworld.org), and our personal observations. Geographic distribution records are based on comparisons with Smythies (1953), Robson (2008), and Thet Zaw Naing (2017). Rankings of conservation threat level are according to the IUCN Red List (2019) and Bird Conservation Society of Thailand (BCST 2020). Our taxonomic nomenclature (common and scientific names) follows Robson (2008) and scientific names for birds mentioned in the text are provided in Table 1.

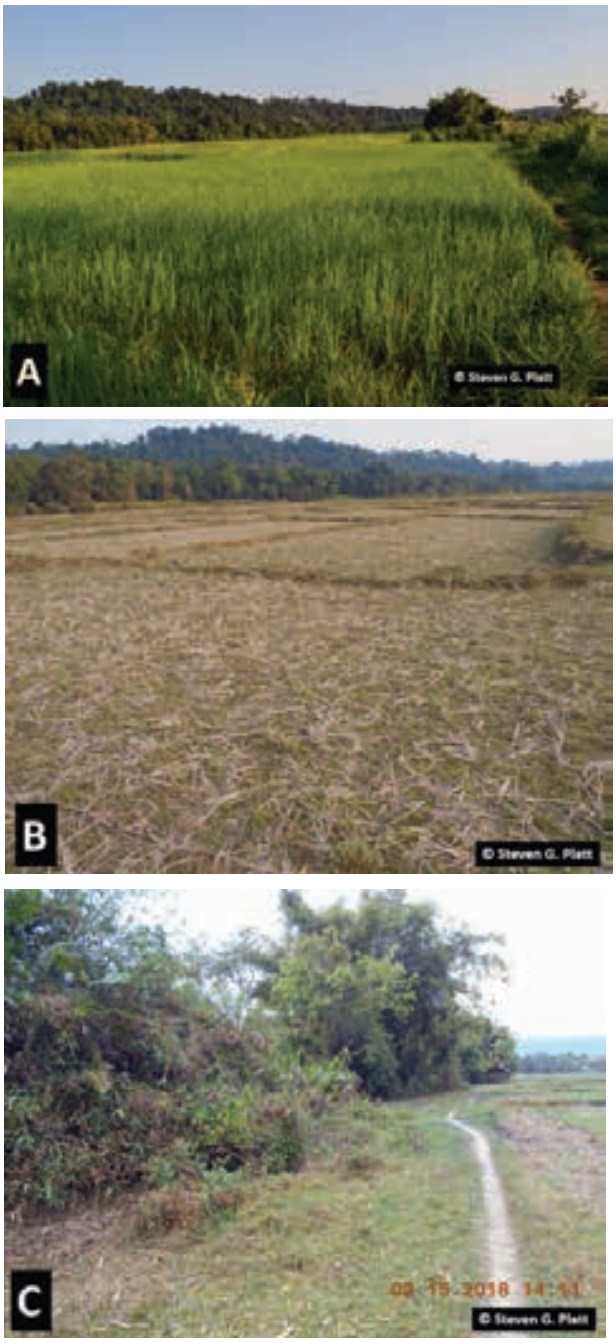

Image 2a–c. Rice field at Limpha in the late wet season just before harvest (2a) and during the dry season (2b); note low berms delineating individual rice paddies. A hedgerow separates village rice field from the Chindwin River (2c).

RESULTS

We recorded a total of 85 species of birds in the rice ecosystem at Limpha in 2013–20 (Table 1). Excluding Buttonquail (see below), we recorded 58 (69.0 %) resident species, 20 migratory species (23.8 %), and six (7.1 %) species with both resident and migrant populations in upper Myanmar (Table 1). Of the 85 species observed on our study site, 53 (62.3 %) and 14 (16.4 %) species were recorded only during the dry and wet seasons, respectively, while 18 (21.1 %) species were present during both seasons. Wading birds (except Cattle Egret), kingfishers, Pheasant-tailed Jacana, and waterfowl were recorded only during the wet season. Twelve (14.1 %) species were recorded only from the hedgerow, while 16 (18.8 %) used the hedgerow as well as rice paddy and/or grass habitats of our study area. Trees in the hedgerow appeared to provide important observation sites for smaller raptors (Collared Falconet, Amur Falcon). Six (7.0 %) species were only recorded while aerially foraging over the study area. We confirmed nesting by four species (4.7 %) of birds within the rice field, while four other species (4.7 %) nested in the adjacent swamp, forest, hedgerow, and village (Table 1). We ranked 52 (61.1 %) species as Common, 23 (27.0 %) as Uncommon, and 10 (11.7 %) as Rare (Table 2); three of the latter were recorded only once during our study (Indian Thick-knee, Amur Falcon, and Glossy Ibis). Indian Thick-knee and Glossy Ibis (Image 6a) have not previously been reported from the Western Ornithological Region of Myanmar. Buttonquail was encountered only in 2014 but observed on multiple occasions. We were unable to confidently identify the Buttonquail to species; three species of Buttonquail potentially occur in the area, one (Yellow-legged Buttonquail) of which is migratory (Table 1). Spotted Dove was the most abundant species in the study area with individual flocks often consisting of >50 birds (Image 6b,c). The Insectivore guild (43 species; 50.5 %) was the best represented feeding guild in our study area, followed by Omnivore (22 species; 25.8 %), Carnivore (12 species; 14.1 %), and Granivore (6 species; 7.0 %) guilds; Frugivore and Nectarivore guilds were each represented by a single species (1.1 %) that was only recorded in the hedgerow (Table 2; Figure 1). We recorded 8 (9.4 %) species of birds in association with domestic ungulates (primarily Water Buffalo), including members of the Omnivore (6 species), Carnivore (1 species), and Insectivore (1 species) feeding guilds (Table 1). We recorded 15 (17.6 %) species of birds foraging at active fires or within recently burned areas, including members of four feeding guilds (Insectivores= 7; Granivore= 4; Carnivore= 2; Omnivore= 2). Our automated game cameras detected three species (Red Junglefowl, White-breasted Waterhen, and Spotted Dove) foraging in piles of discarded rice straw (Images 6d,e), and we directly observed three additional species (Baya Weaver, Scaly-breasted Munia, and White-rumped

Table 1. Annotated checklist of birds observed in a traditional rice ecosystem at Limpha Village, Sagaing Region, Myanmar (2013–20). Season: D= Dry; W= Wet. Asterisk denotes species observed foraging in burned areas. Status: R= Resident; M= Migratory; R/M= Resident and Migratory populations present in Upper Myanmar. Our taxonomic nomenclature (common and scientific names) follows Robson (2008).

		Habitat			
Species	**Season**	**Rice Paddy**	**Grass**	**Hedgerow**	**Status; notes and observations**
Buttonquail (*Turnix* sp.)	D	X	X	–	Observed on multiple occasions in 2014; encountered among weeds around periphery of field and in fallow paddies. Three species of Buttonquail known to occur in this area, including Barred Buttonquail (*T. suscitator*), Yellow-legged Buttonquail (*T. tanki*), and Small Buttonquail (*T. sylvaticus*).
Red Junglefowl (*Gallus gallus*)	D,W	X	X	–	R; Occasionally feeding with domestic ungulates; foraging in piles of discarded rice straw; nesting in forest adjacent to rice field.
White-winged Duck (*Asarcornis scutulata*)	W	–	X	–	R; Observed in flooded rice field during late wet season; occurs in adjacent swamp throughout much of the year.
Lesser Whistling Duck (*Dendrocygna javanica*)	W	X	X	–	R; Nesting in flooded rice and grass
Lineated Barbet (*Megalaima lineata*)	D	–	–	X	R; Fruiting trees in hedgerow are important food resource.
Common Hoopoe (*Upupa epops*)*	D,W	X	X	–	R/M
Indian Roller (*Coracias benghalensis*)	D	X	–	–	R
Plaintive Cuckoo (*Cacomantis merulinus*)	D	–	X	–	R
Asian Koel (*Eudynamys scolopaceus*)	D	–	–	X	R
Greater Coucal (*Centropus sinensis*)	D,W	X	X	–	R; Usually encountered where ungulate "lawns" are interspersed with high grass and scrub.
White-throated Kingfisher (*Halcyon smyrnensis*)	W	X	–	–	R; Occasional in flooded rice paddies.
Common Kingfisher (*Alcedo atthis*)	W	X	X	–	R/M; In flooded rice paddies and around field margins.
Chestnut-headed Bee-eater (*Merops leschenaulti*)*	D	X	X	X	R; Nest burrows constructed in fallow paddies, paddy berms, and ungulate "lawns"; large communal roost in trees at village monastery until nesting begins.
Little Green Bee-eater (*Merops orientalis*)	D	X	X	–	R; Sally from small trees on edge of field and fenceposts.
Blue-tailed Bee-eater (*Merops philippinus*)	W	X	X	–	R
Himalayan Swiftlet (*Aerodramus brevirostris*)	D	–	–	–	M; Aerial foraging
Asian Palm-swift (*Cypsiurus balasiensis*)	D	–	–	–	R; Aerial foraging
Mountain Scops Owl (*Otus spilocephalus*)	D	–	–	X	R
Spotted Dove (*Streptopelia chinensis*)*	D,W	X	X	X	R; Large flocks (>50) feed on spilled rice in threshing areas; nesting and large communal roosts in hedgerow.
Oriental Turtle-dove (*Streptopelia orientalis*)	D	X	X	–	R/M
Common Crane *(Grus grus*)	D	X	X	–	M; Brief (< 24 hrs) migratory stopover in 2019 and 2020.
White-breasted Waterhen (*Amaurornis phoenicurus*)	D,W	X	–	X	R; Feeding in straw piles and on insects flushed by grazing ungulates; common in swamp adjacent to rice field.
Gray-headed Swamphen (*Poryphyrio poliocephalus*)	W	X	X	–	R
Common Moorhen (*Gallinula chloropus*)	W	X	X	–	R; Common throughout year in swamp adjacent to rice field.
Pheasant-tailed Jacana (*Hydrophasianus chirugus*)	W	X	X	–	R
Indian Thick-knee (*Burhinus indicus*)	D	–	X	–	R; Single observation (March 2013).
Small Pratincole (*Glareola lactea*)	D	–	–	–	R; Aerial foraging, often in late afternoon; nesting on nearby island in Chindwin River.
River Lapwing (*Vanellus duvaucelii*)	D,W	X	X	–	R; Nesting on nearby island in Chindwin River.
Grey-headed Lapwing (*Vanellus cinereus*)	D,W	X	X	–	M
Red-wattled Lapwing (*Vanellus indicus*)	D,W	X	X	–	R; Nesting in ungulate "lawn"

		Habitat			
Species	**Season**	**Rice Paddy**	**Grass**	**Hedgerow**	**Status; notes and observations**
Pacific Golden Plover (*Pluvialis fulva*)	W	X	X	–	M
Little Ringed Plover (*Charadrius dubius*)	D	X	X	–	M
Pied Harrier (*Circus melanoleucos*)*	D	X	X	–	M
Collared Falconet (*Microhierax caerulescens*)	W	X	X	X	R
Common Kestrel (*Falco tinnunculus*)*	D	X	X	–	R/M
Amur Falcon (*Falco amurensis*)	W	X	–	X	M; Single record (November 2018).
Black-shouldered Kite (*Elanus caeruleus*)	D	X	X	–	R
Eastern Cattle Egret (*Bubulcus coromandus*)	D,W	X	X	–	R; Feeding on insects flushed by grazing ungulates.
Chinese Pond Heron (*Ardeola bacchus*)	W	X	X	–	R
Black-crowned Night Heron (*Nycticorax nycticorax*)	W	X	X	–	R
Glossy Ibis (*Plegadis falcinellus*)	W	X	–	–	R; Single record (October 2018); foraging in water-filled buffalo wallows.
Long-tailed Broadbill (*Psarisomus dalhousiae*)	D	–	–	X	R; fruiting trees in hedgerow are important food resource; common in adjacent forest.
Golden-fronted Leafbird (*Chloropsis aurifrons*)	D	–	–	X	R
Grey-backed Shrike (*Lanius tephronotus*)*	D	X	X	X	M
Long-tailed Shrike (*Lanius schach*)	D	X	X	–	R
Eastern Jungle Crow (*Corvus levaillanti*)	D	X	–	–	R; Occasionally with domestic ungulates; gleaning ectoparasites?
Black-hooded Oriole (*Oriolus xanthornus*)	D	–	–	X	R; three observations of birds consuming large caterpillars.
Hair-crested Drongo (*Dicrurus hottentottus*)	D	–	–	X	R/M
Black Drongo (*Dicrurus macrocercus*)	D	X	X	–	R/M
Ashy Woodswallow (*Artamus fuscus*)	D	X	X	X	R; Aerial foraging; roost and nest in village.
White-throated Fantail (*Rhipidura albicollis*)	D	–	–	X	R
Bluethroat (*Luscinia svecica*)	D	–	X	–	M
Siberian Rubythroat (*Luscinia calliope*)	D	–	X	–	M
Oriental Magpie-robin (*Copsychus saularis*)	D,W	X	X	–	R
White-tailed Stonechat (*Saxicola leucura*)	D,W	X	X	–	R
Eastern Stonechat (*Saxicola maurus*)	D	X	X	–	M
Pied Bushchat (*Saxicola caprata*)*	D	X	X	–	R; Nesting in rice paddy berm.
Daurian Redstart (*Phoenicurus auroreus*)	D	X	X	–	M
Black Redstart (*Phoenicurus ochruros*)	D	X	X	–	M
Chestnut-tailed Starling (*Sturnus malabaricus*)*	D	–	X	X	R
Common Myna (*Acridotheres tristis*)	D	X	X	X	R
White-vented Myna (*Acridotheres grandis*)	D,W	X	X	–	R; Feeding on insects flushed by grazing ungulates; glean ectoparasites from ungulates.
Collared Myna (*Acridotheres albocinctus*)	D	X	X	–	R; Feeding no insects flushed by grazing ungulates.
Asian Pied Starling (*Gracucpica contra*)*	D	X	X	–	R; Feeding on insects flushed by grazing ungulates.
Grey-throated Sand Martin (*Riparia chinensis*)	D	–	–	–	R; Aerial foraging; scattered nesting colonies on banks of Chindwin River.
Red-rumped Swallow (*Cecropis daurica*)	D	–	–	–	M; Aerial foraging.
Red-whiskered Bulbul (*Pycnonotus jocosus*)	D,W	–	X	X	R; Large communal roost in secondary forest adjacent to rice field.

		Habitat			
Species	**Season**	**Rice Paddy**	**Grass**	**Hedgerow**	**Status; notes and observations**
Red-vented Bulbul (*Pycnonotus cafer*)	D,W	–	X	X	R
Striated Grassbird (*Megalurus palustris*)	D	X	X	–	R; Feeding on insects flushed by grazing ungulates.
Yellow-bellied Prinia (*Prinia flaventris*)	D	–	X	–	R; In high grass of fallow rice paddies; vocalizing males; nesting?
Indian Reed-warbler (*Acrocephalus brunnescens*)	D	–	X	–	M; Present in dense thickets of *Chromolaena odorata.*
Common Tailorbird (*Orthotomus sutorius*)*	D,W	–	X	X	R
Dusky Warbler (*Phylloscopus fuscatus*)	D	–	–	X	M
Chestnut-crowned Warbler (*Seicercus castaniceps*)	D	–	–	X	R
Pin-striped Tit-babbler (*Macronous gularis*)	D	–	–	X	R; Often encountered in bamboo clumps of hedgerow.
Purple Sunbird (*Cinnyris asiaticus*)	D	–	–	X	R
Citrine Wagtail (*Motacilla citreola*)	D	X	X	–	M; Frequently in mixed flocks with White Wagtail and occasionally Red Junglefowl; present on closely cropped lawns and in fallow rice paddies.
White Wagtail (*Motacilla alba*)	D,W	X	X	–	M; See comments for Citrine Wagtail.
Olive-backed Pipit (*Anthus hodgsoni*)*	D	X	X	–	M; Present on closely cropped lawns and fallow rice paddies; avoid areas with thick grass.
Paddyfield Pipit (*Anthus rufulus*)*	D	X	X	–	R; See comments for Olive-backed Pipit.
Rosy Pipit (*Anthus roseatus*)	D	X	X	–	M; See comments for Olive-backed Pipit.
Baya Weaver (*Ploceus phillippinus*)*	D,W	X	X	X	R; Feeding on waste rice in piles of discarded straw; nesting in coconut palms in village.
Scaly-breasted Munia (*Lonchura punctulata*)*	D	X	X	X	R; Feeding on waste rice in piles of discarded straw.
White-rumped Munia (*Lonchura striata*)	D	X	X	X	R; Feeding on waste rice in piles of discarded straw.
Black-faced Bunting (*Emberiza spodocephala*)*	D	X	X	X	M; Commonly encountered among weeds and high grass in fallow rice paddies and in thickets on field margin.

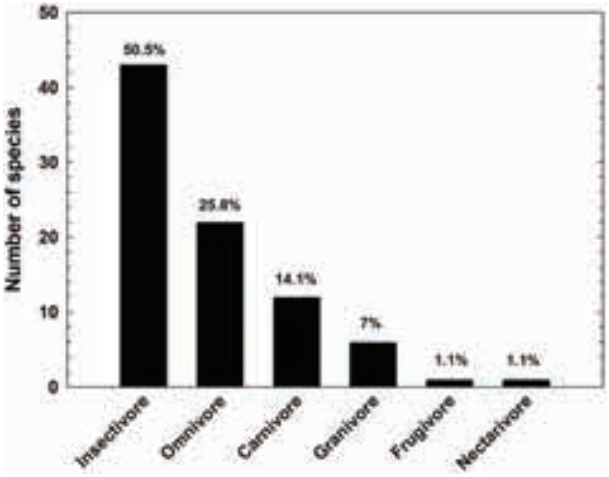

Figure 1. Feeding guilds of birds recorded in a traditional rice field at Limpha, Sagaing Region, Myanmar (2013–20). Percent of total species above columns.

Munia) foraging in piles of rice straw. We recorded 10 species considered to be of conservation concern by the IUCN and BCST in the rice ecosystem at Limpha (Table 3). White-winged Duck was the only Critically Endangered (BCST) or Endangered (IUCN) species that we recorded in the Limpha rice ecosystem (Image 6f). We observed White-winged Duck foraging in shallow water only when the rice field was flooded during the late wet season; however, they were present in the adjacent swamp throughout much of the year so long as water was available.

DISCUSSION

Our study documented significant avian species richness in a traditional rice ecosystem along the Chindwin River in upper Myanmar. In the only similar study available for Myanmar, Suarez-Rubio et al. (2016) recorded 33 species in rice fields along an urban-rural gradient near Mandalay. A comparison with rice ecosystems elsewhere in Asia is challenging because most published studies are region-wide in scope rather than focused on a single site (e.g., Fujioka et al. 2010; Sundar & Subramanya 2010; Wood et al. 2010). A limited

Table 2. Feeding guild and relative abundance of birds observed in a traditional rice ecosystem at Limpha Village, Sagaing Region, Myanmar (2013–20). Feeding guild: C= Carnivore; F= Frugivore; G= Granivore; H= Herbivore; I= Insectivore; O= Omnivore; N= Nectarivore. Relative abundance: C= Common; U= Uncommon; R= Rare.

	Common name	Scientific name	Feeding guild	Relative abundance
1	Buttonquail	*Turnix* sp.	O	U
2	Red Junglefowl	*Gallus gallus*	O	C
3	White-winged Duck	*Asarcornis scutulata*	O	R
4	Lesser Whistling Duck	*Dendrocygna javanica*	O	U
5	Lineated Barbet	*Megalaima lineata*	F	C
6	Common Hoopoe	*Upupa epops*	I	C
7	Indian Roller	*Coracias benghalensis*	I	U
8	Plaintive Cuckoo	*Cacomantis merulinus*	I	U
9	Asian Koel	*Eudynamys scolopaceus*	O	C
10	Greater Coucal	*Centropus sinensis*	O	C
11	White-throated Kingfisher	*Halcyon smyrnensis*	C	C
12	Common Kingfisher	*Alcedo atthis*	C	U
13	Chestnut-headed Bee-eater	*Merops leschenaulti*	I	C
14	Little Green Bee-eater	*Merops orientalis*	I	U
15	Blue-tailed Bee-eater	*Merops philippinus*	I	U
16	Himalayan Swiftlet	*Aerodramus brevirostris*	I	C
17	Asian Palm-swift	*Cypsiurus balasiensis*	I	C
18	Mountain Scops Owl	*Otus spilocephalus*	C	C
19	Spotted Dove	*Streptopelia chinensis*	G	C
20	Oriental Turtle-dove	*Streptopelia orientalis*	G	R
21	Common Crane	*Grus grus*	O	R
22	White-breasted Waterhen	*Amaurornis phoenicurus*	O	C
23	Gray-headed Swamphen	*Poryphyrio poliocephalus*	O	U
24	Common Moorhen	*Gallinula chloropus*	O	C
25	Pheasant-tailed Jacana	*Hydrophasianus chirugus*	C	U
26	Indian Thick-knee	*Burhinus indicus*	O	R
27	Small Pratincole	*Glareola lactea*	I	C
28	River Lapwing	*Vanellus duvaucelii*	I	U
29	Grey-headed Lapwing	*Vanellus cinereus*	I	C
30	Red-wattled Lapwing	*Vanellus indicus*	I	C
31	Pacific Golden Plover	*Pluvialis fulva*	O	U
32	Little Ringed Plover	*Charadrius dubius*	O	U
33	Pied Harrier	*Circus melanoleucos*	C	U
34	Collared Falconet	*Microhierax caerulescens*	C	U
35	Common Kestrel	*Falco tinnunculus*	C	C
36	Amur Falcon	*Falco amurensis*	C	R
37	Black-shouldered Kite	*Elanus caeruleus*	C	U
38	Eastern Cattle Egret	*Bubulcus coromandus*	C	C
39	Chinese Pond Heron	*Ardeola bacchusx*	C	C
40	Black-crowned Night Heron	*Nycticorax nycticorax*	C	U
41	Glossy Ibis	*Plegadis falcinellus*	I	R
42	Long-tailed Broadbill	*Psarisomus dalhousiae*	I	C
43	Golden-fronted Leafbird	*Chloropsis aurifrons*	I	C

	Common name	Scientific name	Feeding guild	Relative abundance
44	Grey-backed Shrike	*Lanius tephronotus*	I	C
45	Long-tailed Shrike	*Lanius schach*	I	C
46	Eastern Jungle Crow	*Corvus levaillanti*	O	C
47	Black-hooded Oriole	*Oriolus xanthornus*	O	C
48	Hair-crested Drongo	*Dicrurus hottentottus*	I	C
49	Black Drongo	*Dicrurus macrocercus*	I	R
50	Ashy Woodswallow	*Artamus fuscus*	I	C
51	White-throated Fantail	*Rhipidura albicollis*	I	U
52	Bluethroat	*Luscinia svecica*	I	U
53	Siberian Rubythroat	*Luscinia calliope*	I	U
54	Oriental Magpie-robin	*Copsychus saularis*	I	C
55	White-tailed Stonechat	*Saxicola leucura*	I	C
56	Eastern Stonechat	*Saxicola maurus*	I	C
57	Pied Bushchat	*Saxicola caprata*	I	C
58	Daurian Redstart	*Phoenicurus auroreus*	I	R
59	Black Redstart	*Phoenicurus ochruros*	I	R
60	Chestnut-tailed Starling	*Sturnus malabaricus*	O	C
61	Common Myna	*Acridotheres tristis*	O	C
62	White-vented Myna	*Acridotheres grandis*	O	C
63	Collared Myna	*Acridotheres albocinctus*	O	U
64	Asian Pied Starling	*Gracucpica contra*	O	C
65	Grey-throated Sand Martin	*Riparia chinensis*	I	C
66	Red-rumped Swallow	*Cecropis daurica*	I	C
67	Red-whiskered Bulbul	*Pycnonotus jocosus*	O	C
68	Red-vented Bulbul	*Pycnonotus cafer*	O	C
69	Striated Grassbird	*Megalurus palustris*	I	R
70	Yellow-bellied Prinia	*Prinia flaventris*	I	C
71	Indian Reed-warbler	*Acrocephalus brunnescens*	I	U
72	Common Tailorbird	*Orthotomus sutorius*	I	C
73	Dusky Warbler	*Phylloscopus fuscatus*	I	C
74	Chestnut-crowned Warbler	*Seicercus castaniceps*	I	U
75	Pin-striped Tit-babbler	*Macronous gularis*	I	C
76	Purple Sunbird	*Cinnyris asiaticus*	N	C
77	Citrine Wagtail	*Motacilla citreola*	I	C
78	White Wagtail	*Motacilla alba*	I	C
79	Olive-backed Pipit	*Anthus hodgsoni*	I	C
80	Paddyfield Pipit	*Anthus rufulus*	I	C
81	Rosy Pipit	*Anthus roseatus*	I	U
82	Baya Weaver	*Ploceus phillippinus*	G	C
83	Scaly-breasted Munia	*Lonchura punctulata*	G	C
84	White-rumped Munia	*Lonchura striata*	G	C
85	Black-faced Bunting	*Emberiza spodocephala*	G	C

Image 3a–c. Rice seedlings (3a) are germinated in specially prepared beds, transported to the field (3b), and then hand-planted in paddies by villagers (3c).

Image 4. Harvesting and threshing the rice is a communal activity at Limpha.

Table 3. Species of conservation concern recorded in a rice agroecosystem at Limpha Village, Sagaing Region, Myanmar (2013-2020). Rankings of threat level from International Union for Conservation of Nature and Natural Resources (IUCN) and Bird Conservation Society of Thailand (BCST). Threat level: CR= Critically Endangered; E= Endangered; VU= Vulnerable; NT= Near Threatened; LC= Least Concern.

	Common name	Scientific name	IUCN	BCST
1	White-winged Duck	*Asarcornis scutulata*	EN	CR
2	Small Pratincole	*Glareola lactea*	LC	NT
3	River Lapwing	*Vanellus duvaucelii*	NT	VU
4	Pied Harrier	*Circus melanoleucos*	LC	NT
5	Collared Falconent	*Microhierax caerulescens*	LC	NT
6	Black-shouldered Kite	*Elanus caeruleus*	LC	NT
7	Long-tailed Shrike	*Lanius schach*	LC	VU
8	Grey-throated Sand Martin	*Riparia chinensis*	LC	VU
9	Red-whiskered Bulbul	*Pycnonotus jocosus*	LC	VU
10	Black-faced Bunting	*Emberiza spodocephala*	LC	NT

number of site-based studies are available, however, from rice ecosystems in India and Sri Lanka; these found 34–65 species of birds (Nathan & Rajendran 1982; Srinivasulu et al. 1997; Borad et al. 2000; Bambaradeniya et al. 2004) suggesting that avian species richness at our study site is comparatively quite high, even after removing those species (N= 12) recorded only in the hedgerow and other species more typical of forested habitats (Red Junglefowl, White-winged Duck). That said, among-site comparisons must be undertaken with caution given differences in sampling methodologies, geographic location, farming intensity, position within migratory flyways, and differing systems of cultivation (Hohman et al. 1994; Valente et al. 2012; Cunningham et al. 2013). Most of the species we recorded at Limpha are birds of open-country, grassland, and early successional vegetation, which is typical of species inhabiting not just rice ecosystems (Sundar & Subramanya 2010), but agricultural habitats in general (Friskhoff et al. 2014; Kumar & Sahu 2020). In common with most studies of birds in rice ecosystems (Fasola & Ruiz 1996; Townsend et al. 2006; Fujioka et al. 2010; Pierluissi 2010; Sundar & Subramanya 2010), the rice field at Limpha appears to be used by birds primarily as foraging rather than breeding habitat.

We attribute the relatively high levels of bird species richness at Limpha to the low intensity (i.e., non-mechanized, absence of agrochemicals) farming practices used by villagers to produce a single crop of

rice each year. Farming intensity is known to determine the abundance and diversity of birds within agricultural landscapes (Cunningham et al. 2013), with intensification usually leading to declines in avian biodiversity (Maeda 2001; Ibáñez et al. 2010; Friskhoff 2014). At Limpha, farming practices create a heterogeneous mosaic of different habitats within the rice monoculture that includes rice paddies under cultivation, fallow rice paddies in various successional stages, closely grazed "lawns" maintained by domestic ungulates, tangles of weeds and high grass, and a hedgerow with vertical woody structure. Previous studies at varying spatial scales have consistently found that landscape heterogeneity is the single most important factor in determining species richness of birds (Böhning-Gaese 1997; Pino et al. 2000; Söderström et al. 2003; Tews et al. 2004). Moreover, the dearth of agrochemical inputs at our study site probably favors the development of speciose communities of arthropods and weeds (Fasola & Ruiz 1996; Bambaradeniya & Amarasinghe 2003; Ibáñez et al. 2010), many of which are important food resources for birds (Stafford et al. 2010). Finally, the close proximity of forest, swamp, and the Chindwin River provides cover and additional food resources for birds using the rice field at Limpha and probably serves as a source for some species (e.g., White-winged Duck, River Lapwing, Small Pratincole, Grey-throated Sand Martin) that would otherwise be unlikely to occur in more expansive and homogenous rice landscapes (e.g., Pierluissi 2010; Kumar & Sahu 2020).

We recorded considerably more species of birds during the dry season in comparison to the wet season, and attribute this disparity to the influx of Palearctic migrants that occurs during the dry season in upper Myanmar; i.e., almost 25 % of the species we recorded at Limpha were migrants. We recorded wading birds and waterfowl at Limpha only during the wet season, most likely because moist-soil and flooded habitat was unavailable in the rice field during the dry season. Irrigation reservoirs and water-filled ditches are absent from the rice ecosystem at Limpha, and these habitats can serve as critical dry season refugia for wetland birds when flooded fields are unavailable (Herzon & Helenius 2008; Valente et al. 2012). Although not included as part of our study, the swamp adjacent to the rice field appears to function in this capacity, harboring wetland birds (e.g., White-winged Duck, Common Moorhen, and White-breasted Waterhen) throughout most of the dry season.

Rice seed is perhaps the most important food resource available to birds in rice agroecosystems (Borad et al. 2000; Stafford et al. 2010). Rice seed is a concentrated energy source made available to birds when spilled during harvest, i.e., "waste rice" (Stafford et al. 2006), but birds also forage on recently planted rice seeds, rice seedlings, and grains in maturing seed heads before harvest (Stafford et al. 2010). Waste rice is most abundant immediately after harvest and resists decomposition (Stafford et al. 2006), and in North America and Japan, the dry mass of rice seed remaining in fields after mechanized harvest ranged from 56–627 kg/ha (Stafford et al. 2010). Because hand threshing is more efficient than mechanical threshing, lesser but nonetheless significant amounts of rice seeds are lost to wastage in traditional rice ecosystems (Borad et al. 2000). For example, in India Borad et al. (2000) found the dry mass of rice seed remaining in fields after hand threshing ranged from 60-199 kg/ha. Our observations suggest that waste rice is an abundant and important food resource for several species of birds at Limpha, most notably small seed-eaters, Spotted Dove, and Red Junglefowl. Additionally, piles of rice straw left in fields after harvesting contain abundant waste rice and arthropods (Bird et al. 2000; Lawler & Dritz 2005) and as such are important avian foraging sites in the Limpha rice ecosystem.

Our observations suggest that free-ranging ungulates, primarily Water Buffalo, provide a number of benefits for birds in the Limpha rice ecosystem. As reported for wild ungulates and birds (Heatwole 1965; Dean & MacDonald 1981; Isenhart & DeSante 1985), we observed two common interactions between domestic ungulates and birds: 1) grazing ungulates acted as "beaters" to flush insects towards waiting birds, and 2) cleaning symbiosis, whereby birds gleaned nutritionally rich ectoparasites directly from ungulates. Water Buffalo also appear to function as "ecosystem engineers" (sensu Jones et al. 1994) in the Limpha rice ecosystem by maintaining closely grazed "lawns" favored by some birds (e.g., Red Junglefowl, wagtails, pipits, lapwings), and creating wallows that harbor invertebrates, small fish, and amphibians and serve as foraging sites for wading birds during the wet season. Furthermore, Water Buffalo disperse seeds, especially those of small-seeded herbs and grasses inadvertently consumed while grazing (Corlett 2017), and possibly aid in the passive dispersal of aquatic invertebrates in the same manner described for large wallowing mammals in Africa (Vanschoenwinkel et al. 2011). Wild Water Buffalo once played a critical role in maintaining the ecological integrity of wetlands in southeastern Asia (Wharton 1968), and Grey et al. (2019) recommend using domestic

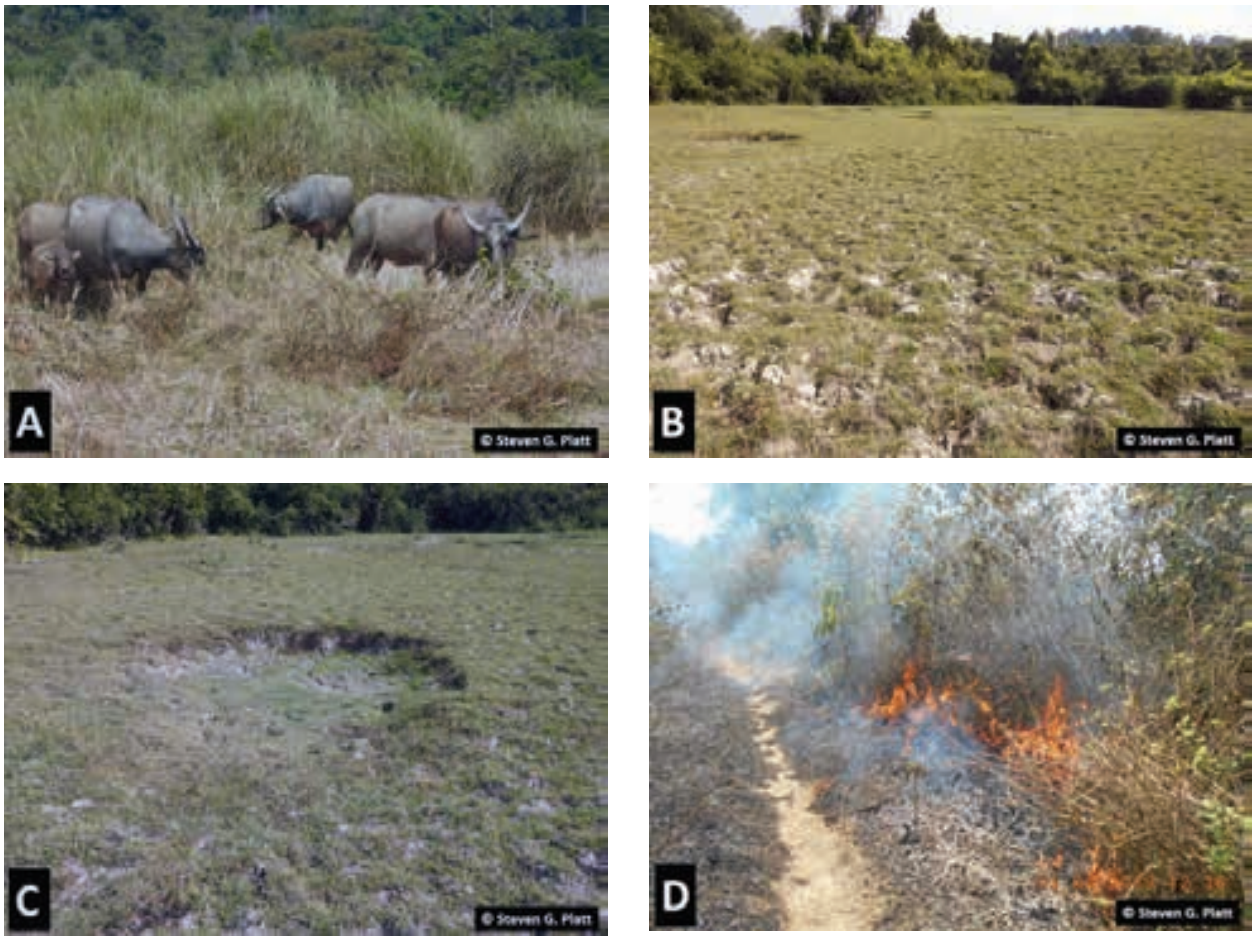

Image 5a–d. Village Water Buffalo grazing in fallow rice paddies with typical vegetation of grasses, herbaceous weeds, and scattered perennial shrubs (5a). Grazing water buffalo maintain "lawns" of closely cropped grass around the periphery of the rice field (5b). Water Buffalo wallow during the dry season (5c). These wallows contain water throughout much of the year. Low-intensity ground fire ignited to prevent encroachment of weeds and other vegetation into rice field (5d).

Water Buffalo as ecological surrogates for extinct (or nearly so) megafauna to replicate historic patterns of grazing and wallowing in rewilding projects.

The effects of anthropogenic burning on wildlife in southeastern Asia remain largely unstudied (Rabinowitz 1990). Dry season burning at Limpha is no doubt at least partly responsible for the heterogeneous mosaic of early successional vegetation in the rice ecosystem (e.g., Peterson & Reich 2001). Additionally, we frequently observed birds in association with fires and in recently burned-over areas, suggesting burning is important in ways other than maintaining early successional habitats. Fires can remove concealing vegetative cover and flush insects and small vertebrates, providing foraging opportunities for insectivorous and carnivorous birds as reported by others (Komarek 1969; Woinarski & Recher 1997; Bonta et al. 2017), and by incinerating ground litter, fires expose seeds that would otherwise remain hidden and unavailable to birds (Komarek 1969; Woinarski & Recher 1997). Furthermore, arthropod abundance is generally high in post-fire regrowth, creating foraging opportunities favorable for insectivorous birds (Woinarski & Recher 1997). At Limpha, fires ignited to remove piles of rice straw leftover from the harvest expose waste rice, which is resistant to burning (Havens et al. 2009), and in turn attracts flocks of foraging Spotted Dove and small seed-eaters. Anthropogenic dry season burning as practiced at Limpha would seem to pose little threat to nesting birds because most species reproduce during the wet season when moist fuel conditions preclude ignition.

Similar to our observations at Limpha, Sundar & Subramanya (2010) found the guild structure of birds using rice fields in the Indian Subcontinent was dominated by insectivorous and omnivorous species. Although the most abundant species at Limpha (Spotted Dove) is largely granivorous (Fujioka et al. 2010), we otherwise recorded few granivorous birds, which is

Image 6a–e. Birds of the Limpha rice field. Two Glossy Ibis (previously unrecorded in this region of Myanmar) foraging on the flooded margins of the rice field near the end of the wet season (6a). Spotted Doves were the most abundant species of bird recorded in the rice field. Large flocks gathered in late afternoon to roost in the hedgerow (6b). Spotted Doves often foraged on bare soil exposed by dry season burns (6c). Camera trap images of White-breasted Waterhen (6d) and Red Junglefowl (6e) foraging in piles of discarded rice straw remaining after the harvest. White-winged Duck was the only Critically Endangered or Endangered Species recorded in the Limpha rice field (6f).

somewhat surprising given the abundance of waste rice and weed seeds typically present in rice ecosystems (Stafford et al. 2010). Our results stand in contrast to previous mist-netting studies that yielded primarily seed-eating birds from rice fields in Malaysia (reviewed by Bambaradeniya & Amarasinghe 2003).

The preponderance of insectivorous species in rice ecosystems suggests this avifauna could be at particular risk from pesticide exposure (Czech & Parsons 2002; Ibáñez et al. 2010). Pesticides can result in direct mortality as well as sublethal effects that include reproductive and behavioral impairment (Fry 1995; Smith et al. 2010; Parsons et al. 2010). Pesticides can also negatively impact local avian abundance by reducing or eliminating insect prey (Ibáñez et al. 2010; Parsons et al. 2010; Nocera et al. 2012), and widespread use of herbicides can eliminate important food plants (Czech & Parsons 2002; Stafford et al. 2010). Pearlstine et al. (2004) suggest that some agricultural lands could function as population sinks by attracting birds to use

habitat that is potentially hazardous to their survival owing to the likelihood of pesticide exposure. Pesticide and herbicide use is currently of little concern at Limpha because capital is unavailable to purchase agrochemicals, although this situation could change as villagers become increasingly enmeshed in the global economy.

The importance of rice ecosystems as foraging and in some cases, breeding habitat for threatened and endangered birds is well-documented (e.g., Pearlstine et al. 2004; Yu et al. 2006; Acosta et al. 2010; Elphick 2010; Van der Weijden 2010; Pickens & King 2011). Although the threat status for most of the species we recorded at Limpha is listed as 'Least Concern' by the IUCN (IUCN 2019) and BCST (2020), complacency is unwarranted because even common species can undergo rapid and catastrophic declines if land-use changes or agriculture intensifies (Newton 2004; Friskhoff et al. 2014; Amano et al. 2010). This is certainly the case in Europe where some of the most threatened birds were once considered common farmland species (Fuller et al. 1995; Sotherton 1998; Van der Weijden 2010). Similarly, a trend towards "clean farming" practices (e.g., removal of hedgerows, chemical elimination of weeds and brush, etc.) in agricultural landscapes of the Southeastern United States is in part responsible for declines among Northern Bobwhite *Colinus virginanus* (Linnaeus, 1758) populations (Brennan 1991; Hernández et al. 2013). In rice ecosystems, intensification usually involves a transition to mechanized, capital-intensive production systems, the planting of rapidly maturing, high-yielding rice varieties that require high inputs of agrochemicals, and substantial increases in water consumption (Bambaradeniya & Amarasinghe 2003). In Japan, several species of once common rice field birds are now declining, largely as the result of agricultural intensification (Amano et al. 2010; Kasahara & Koyama 2010). Intensification of rice agriculture probably represents the single greatest threat to avian biodiversity in traditional rice ecosystems in Myanmar and elsewhere (Bambaradeniya & Amarasinghe 2003).

In conclusion, our case study at Limpha demonstrates that a relatively small traditional rice ecosystem in Myanmar can host a rich assemblage of birds, including species of conservation concern and others that are likely to be so in the near future. In accordance with species-area relationships (Bennett et al. 2006), we predict that even higher levels of avian richness will be found in larger rice ecosystems elsewhere in Myanmar. Anecdotally, this indeed seems to be the case in an extensive (151 ha) rice ecosystem surrounding Htamanthi Village (ca. 65 km downstream from Limpha) where our recreational bird-watching has documented a number of species of shorebirds, wading birds, waterfowl, passerines, and raptors not recorded at Limpha. Given these apparent high levels of observed avian biodiversity, traditional rice agriculture seems compatible with conservation objectives in the ecologically-sensitive buffer zone surrounding Htamanthi Wildlife Sanctuary. According to Bambaradeniya & Amarasinghe (2003), traditional rice ecosystems that have been cultivated over long periods can be considered stable, climax communities that meet the criteria of sustainability; i.e., maintain or enhance the quality of the environment and conserve natural resources. Finally, we close with a cautionary caveat and emphasize that our study constitutes but a single datum that requires replication before generalizations can be made concerning the value of traditional rice ecosystems to avian conservation in Myanmar. To this end, additional studies of rice field biodiversity should be undertaken, especially in central Myanmar and the Ayeyarwady Delta, where the bulk of the national rice crop is produced (Hla Myo Thwe et al. 2019).

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အကျဉ်းချုပ်: ဆန်စပါးစိုက်ပျိုးရေး ဂေဟစနစ်များသည် ငှက်မျိုးစိတ်များ၏ အစားအသောက် နှင့် အသိုက် ဆောက်လုပ် မျိုးပွားခြင်းများအတွက် များစွာအထောက်အကူပြုပါသည်။ မြန်မာနိုင်ငံသည် ဆန်စပါးကို အဓိကစိုက်ပျိုးထုတ်လုပ်သော နိုင်ငံဖြစ်ပြီး ငှက်မျိုးစိတ်များ၏ စိုက်ပျိုးရေး ဂေဟစနစ်များအပေါ် ဆက်စပ်၊ မှီခိုနေမှုများအား သိရှိနိုင်ဖို့ လေ့လာသုတေသနပြုရန် အများကြီးလိုအပ်လျက်ရှိပါသည်။ မြန်မာနိုင်ငံအထက်ပိုင်း လင်းဖါးကျေးရွာရှိ မိရိုးဖလာ ဆန်၊ စပါးစိုက်ကွင်းများ၏ ငှက်မျိုးစိတ်ကြွယ်ဝမှုများ၏ လေ့လာမှု စစ်တမ်းတစ်ခု၏ ရလဒ်များကို တင်ပြချင်ပါသည်။ လင်းဖါးကျေးရွာရှိ ဆန်၊စပါးစိုက်ခင်းသည် ၁၇.၅ ဟတ်တာ ကျယ်ဝန်းပြီး ဓာတုဆေးဝါးများ (ဓါတ်မြေဩဇာနှင့်ပိုးသတ်ဆေး) အသုံးပြုခြင်းမပြုဘဲ နှစ်စဉ် သီးနှံတစ်မျိုး သာ စိုက်ပျိုးလျက်ရှိပါသည်။ ကျေးရွာပိုင်မြေများသည် ထမံသီတောရိုင်းတိရစ္ဆာန် ဘေးမဲ့တော ၏ ကြားခံနယ်နိမိတ်နှင့်ဆက်စက်လျက်ရှိပါသည်။ ငှက်သုတေသန ကွင်းဆင်းလုပ်ငန်းများကို ၂၀၁၃ ခုနှစ်မှ ၂၀၂၀ ခုနှစ်အထိ မိုးရာသီ နှင့် ပွင့်လင်းရာသီအချိန်များတွင် ဆောင်ရွက်ခဲ့ပါသည်။ ဆောင်းခိုငှက်မျိုးစိတ် ၂၁ မျိုး၊ ဌာနေငှက်မျိုးစိတ် ၅၈ မျိုး၊ မြန်မာပြည်မြောက်ပိုင်း၏ ဌာနေငှက် နှင့် ဆောင်းခိုငှက်မျိုးစိတ် ၆ မျိုးအပါအဝင် စုစုပေါင်း ငှက်မျိုးစိတ် ၈၅ မျိုးကို မှတ်တမ်း တင်နိုင်ခဲ့ပြီး ထိန်းသိမ်းရေးအတွက် အရေးပါသော ငှက်မျိုးစိတ် ၁၀ မျိုး ပါဝင်ပါသည်။ ဆောင်းခိုငှက်များ ရောက်ရှိကျက်စားခိုနှုန်းဖြစ်သော ပွင့်လင်းရာသီသည် ငှက်မျိုးစိတ်များ ပေါကြွယ်ဝဆုံးသော အချိန်ဖြစ်ပါသည်။ စစ်တမ်းကောက်ယူမှုအတွင်း သဘာဝတွင်ပေါများစွာ ရှိသော ငှက်မျိုးစိတ် ၅၂ မျိုး၊ ပေါများစွာတွေ့ရလေ့မရှိသော မျိုးစိတ် ၂၃ မျိုး နှင့် ရှားပါးမျိုးစိတ် ၁၀ မျိုးကို မှတ်တမ်းတင်နိုင်ခဲ့ပါသည်။ ငှက်မျိုးစိတ်အများစုမှာ လယ်ကွင်းများတွင် မျိုးပွား၊ အသိုက်ဆောက်လုပ်ခြင်းထက် အစားအစာ စားသုံးရာနေရာအဖြစ် အသုံးပြုမှု ပိုမိုများပါး ပါသည်။ အများဆုံးငှက်မျိုးစိတ်များမှာ အင်းဆက်စားသုံးသောငှက်မျိုးစိတ်များ (၄၃ မျိုး) ဖြစ်ပြီး၊ ဒုတိယအများဆုံး မျိုးစိတ်မှာ အစာမျိုးစုံစားသုံးသောမျိုးစိတ်များ (၂၂ မျိုး) ဖြစ်ပြီး၊ အသားစားမျိုးစိတ် (၁၂ မျိုး)၊ စပါးကဲ့သို့သီးနှံများစားသော မျိုးစိတ်များ (၆ မျိုး)၊ အသီးစားမျိုးစိတ် (၁ မျိုး) နှင့် ဝတ်ရည်စုတ်မျိုးစိတ် (၁ မျိုး) စသည်တို့ကို လေ့လာတွေ့ရှိရပါသည်။ လူတို့မွေးမြူထားသော ကျွဲနွားဆက်စပ်သော ငှက်မျိုးစိတ် (၈) မျိုး၊ လယ်ကွင်းများအတွင်း မီးလောင်နေသောနေရာများ၊ မီးလောင်ထားသော နေရာများတွင် အစာစားသောငှက်မျိုးစိတ် (၁၅) မျိုးတို့ကိုလဲ တွေ့ရှိခဲ့ပါသည်။ ကောက်ရိုးပုံများသည် ငှက်မျိုးစိတ်များ၏ အရေးကြီးသော အစားအစာနေရာများ ဖြစ်ပါသည်။ ဆန်စပါး အလွန် အကျွံစိုက်ပျိုးထုတ်လုပ်မှုမရှိမှု၊ မတူကွဲပြားသော နေရင်းဒေသများတည်ရှိမှု နှင့် ချင်းတွင်းမြစ်၊ သဘာဝသစ်တော၊ စိမ့်စမ်းရေးများနှင့် နီးကပ်စွာ တည်ရှိမှု စသည်တို့သည် မတူကွဲပြားသော ငှက်မျိုးစိတ် ပေါကြွယ်ဝမှုများကို ထောက်ပံ့ပေးလျက်ရှိပါသည်။ ရေရှည်တွင် ဆန်စပါး စိုက်ပျိုး ထုတ်လုပ်မှုများ ကို အလွန်အကျွံ တိုးချဲ့လာလျှင် လင်းဖါးကျေးရွာရှိ လယ်ကွင်းများ အတွင်း ငှက်မျိုးစိတ် ပေါကြွယ်ဝစွာကျက်စားနေမှုများကို ထိခိုက်လာနိုင်ပါသည်။ ကျွန်တော် တို့၏ သုတေသနပြု လေ့လာမှုအရ လင်းဖါးကျေးရွာရှိ မိရိုးဖလာ ဆန်စပါး စိုက်ပျိုး ထုတ်လုပ်မှုများသည် ထမံသီဘေးမဲ့တော၏ ကြားခံနယ်မြေ ထိန်းသိမ်းရေး ရည်မှန်းချက် များနှင့် သဟဇာတဖြစ်လျက်ရှိပါသည်။ သို့သော် မိရိုးဖလာ ဆန်စပါး စိုက်ပျိုးရေး ဂေဟစနစ် တန်ဖိုးသည် မြန်မာငှက်မျိုးစိတ်များ ထိန်းသိမ်းရေးလုပ်ငန်းများအတွက် အရေးပါ ဆက်စပ်ပတ်သက်နေမှုကို ပြသနိုင်ရန် ကျွန်တော်တို့သည် သုတေသနလုပ်ငန်းများ ကို ပိုမို ဆက်လက် လုပ်ကိုင်ရန်လိုအပ်ပါသည်။

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COMMUNICATION

Conservation status, feeding guilds, and diversity of birds in Daroji Sloth Bear Sanctuary, Karnataka, India

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Abstract: The present study was carried out to investigate the importance of habitat quality for the diversity, distribution, and abundance of avifauna in Daroji Sloth Bear Sanctuary, Ballari District from February 2015 to January 2016. A total number of 189 species of birds, belonging to 62 families and 18 orders were recorded during the survey. A family-wise analysis showed that the families Accipitridae (12 species), followed by Muscicapidae (11 species), Ardeidae & Alaudidae (8 species each), and Cuculidae (7 species) dominated the avifauna of the region. The residential status of birds revealed that 74% (140 species) were resident, 23% (44 species) were winter, 2% (3 species) were summer and 1% (2 species) was passage migrant's species. The study resulted in the recording of fives globally Near Threatened category, viz, Painted Stork, Black-headed Ibis, Oriental Darter, River Tern, and Pallid Harrier; and two Vulnerable species, viz, Yellow-throated Bulbul and Woolly-necked Stork. The feeding guild analysis revealed that the insectivorous guild has the most number of recorded avian species (33%, 63 species), followed by carnivorous (31%, 58 species) and least by nectarivorous (1%, 2 species). This study provides baseline data for monitoring the avifauna in the sanctuary and demonstrates the importance of the area in bird conservation. The study also highlights the negative impact of anthropogenic activities as the main cause for the loss of diversity of both birds and their habitat and the urgent need to conserve this biodiversity-rich area with long-term monitoring programs.

Keywords: Avifaunal diversity, Ballari District, feeding guild, relative abundance, southern Deccan Plateau, threatened fauna, Yellow-throated Bulbul.

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Author contributions: MNH involved in the design of the research, data collection, analysis and write up of the manuscript. ABS participated in survey, data collection and identification as well as write up of the manuscript. BBH contributed in supervision of data collection and manuscript preparation.

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INTRODUCTION

Birds are good indicators of the ecological status of any ecosystem (Bilgrami 1995). Ecologically; birds are of tremendous importance because of their key roles as pollinators and agents of seed dispersal (Nason 1992; Bibi & Ali 2013). Changes in their population, behavior patterns, and reproductive ability have been used mostly to examine the long-term effects of habitat fragmentation (Harisha & Hosetti 2009). Given the significance of birds for conservation planning and environmental assessments, there is a need for a better ecological understanding of the role of bird diversity patterns and community structure in conservation decision-making (Kati & Sekercioglu 2006).

Forests attract a significant number of birds because they provide suitable habitats for most birds, especially those birds associated with vegetation, and for most, the existence of trees is a vital component of their life cycle. The birds' level of interest in various forests depends on the age of the stand. The composition of bird species is highly related to the vegetation structure of forests (Robertson & Hackwell 1995). The habitat type and structural complexity influence species diversity and the inter-relationship between vegetation and avian population (MacArthur & MacArthur 1961).

Approximately, 9,990 bird species are recorded on our planet and the Indian subcontinent is home to 1,263 bird species (Praveen et al. 2016a), constituting about 12% of the world avifauna. Of these, approximately 531 species of birds have been reported from Karnataka. Due to geographical variation, the Deccan Plateau region of India possesses great diversity in agricultural as well as wild floral and faunal diversity. Therefore, understanding the diversity and structure of bird communities is essential to delineate the importance of regional or local landscapes for avian conservation (Kattan & Franco 2004).

Very few avifaunal works have been done in Daroji Sloth Bear Sanctuary (DSBS). Previously, Neginhal et al. (2003) reported 90 species of birds. Later, Harisha (2013) recorded 135 bird species belonging to 43 families under 16 orders from 2009 to 2012. Except for these earlier reports, no detailed long-term studies have been made on the biodiversity of birds in the study area. In this context, the present study was undertaken to highlight the status, composition, feeding guilds, and diversity of birds of DSBS, Ballari District, Karnataka.

MATERIALS AND METHODS

Study Area

Daroji Sloth Bear Sanctuary is located between Hospet and Sandur Taluk of Ballari District of Karnataka and is spread over 82.72 km^2 (Figure 1). It is about 50 km from Ballari and about 15 km from the World Heritage Site Hampi. In October 1994, the Government of Karnataka declared 5587.30 ha of the Bilikallu Forest Reserve as Daroji Sloth Bear Sanctuary. After 15 years, in October 2009, the government added 2685.50 ha of the Bukkasagara Forest Reserve to the sanctuary. This resulted in the overall area increasing from 5587.3 ha to 8272.8 ha. It lies between 15.269^{0}N and 76.571^{0}E with an average elevation of 521 m, temperature of 20–46°C & annual rainfall of 450–500 mm. It is a strewn hillock that stretches between Daroji of Sandur Taluk and Ramasagar of Hospet taluk in Ballari District (Image 1, 2). The sanctuary has rich floral and faunal diversity. The flora of this sanctuary is primarily dry deciduous scrub and southern thorn forests. The typical species of scrub jungle, *Grewia damine* is found to be the most abundant species of the plant followed by *Senegalia catechu* and *Albizia amara* in the habitat. It has a very stable population of Sloth Bears and they reside in the numerous caves found in the hillocks within the sanctuary. Leopards, monitor lizards, mongoose, pangolins, and Star Tortoises are some of the other animals that abound in the sanctuary.

Sampling method

A study on avifaunal diversity was carried out from February 2015 to January 2016. The line transect method was used, as the habitat of the study area was of open type (Sutherland et al. 2005). Six line transects were set up, which were approximately 500m in length and 20–30 meters in width. The transect line was walked at a constant pace for approximately 30 minutes. Twelve field visits (1 visit per month) were conducted observing the status and diversity of birds. The field surveys were conducted in the morning (0600–1000 h) and the evening (1600–1900 h), depending on the season when birds were most active. Birds were observed using the Olympus binoculars (10x50), and were identified with the help of field guides (Ali & Ripley 1983; Grimmett et al. 2011) and were given standardized common and scientific names (Praveen et al. 2016b). The residential status of the birds was worked out and birds are grouped under different categories like resident, summer, passage, and winter migrants or visitors depending on their timing and duration of occurrence (Grimmett et

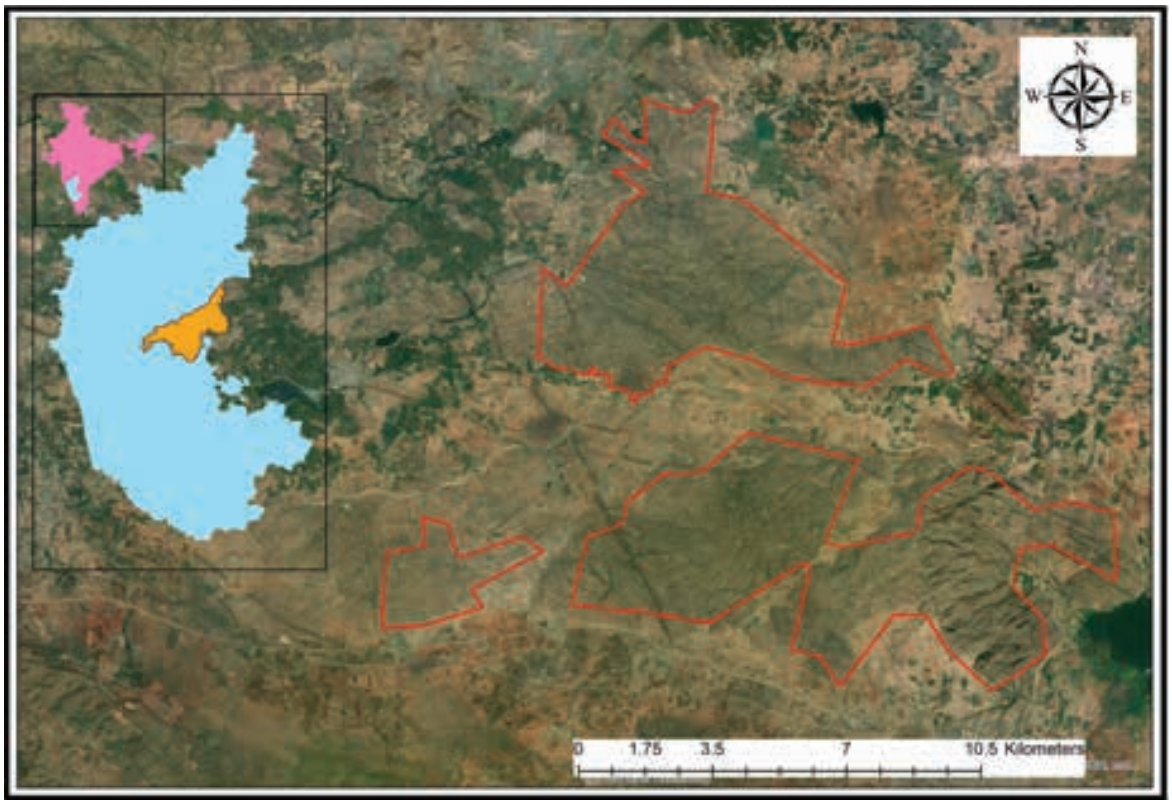

Figure 1. Daroji Sloth Bear Sanctuary, Ballari District, Karnataka.

Image 1. Study area during dry seasons. © M.N. Harisha

Image 2. Study area during wet seasons. © M.N. Harisha

al. 2011). The International Union for the Conservation of Nature (IUCN) Red List status was additionally used to compare the local status with the global status. During the surveys, other information or threats to bird conservation were noted. The data recorded in each survey were kept separate, and later analyzed for relative abundance based on the frequency of bird sightings and are categorized, as very common (Vc) sighted >10 times; common (Co) sighted 7–9 times; uncommon (Uc) sighted 3–6 times; rare (Ra) sighted 1–2 times (MacKinnon & Phillipps 1993). Feeding guilds were classified based on direct observations and available literature (Ali & Ripley 1987). The relative diversity (RDI) of families was calculated adopting the following formula (Torre-Cuadros et al. 2007):

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

RESULTS AND DISCUSSION

Avian diversity

A total of 189 species of birds belonging to 62 families under 18 orders were recorded from DSBS. Nonpasserine birds dominated the diversity with 98 species (52%) compared to passerine birds (91 species, 48%) (Table1). The present investigation revealed that out of 62 families, Accipitridae dominated the study area with maximum number of species and RDI value, i.e., 12 species (RDI= 6.45%), followed by Muscicapidae with 11 species (RDI= 5.91%), Ardeidae and Alaudidae with 8 species (RDI= 4.30%) each, Cuculidae with seven species (RDI= 3.76%), Phasianidae, Scolopacidae, Cisticolidae with six species (RDI= 3.23%) each, Anatidae, Columbidae, Motacillidae, Hirundinidae, Sturnidae, Rallidae with five species (RDI= 2.69%) each, Laniidae, Estrildidae, Pycnonotidae, Leiothrichidae with four species (RDI= 2.15%) each, Ciconiidae, Phalacrocoracidae, Charadriidae, Strigidae, Picidae, Alcedinidae, Corvidae, Emberizidae, Acrocephalidae, Phylloscopidae with three species (RDI= 1.61%) each, Pteroclidae, Apodidae, Threskiornithidae, Jacanidae, Meropidae, Falconidae, Psittaculidae, Campephagidae, Dicruridae, Dicaeidae, Nectariniidae, Ploceidae, Passeridae, Sylviidae with two species (Rdi=1.08%), Podicipitidae, Caprimulgidae, Anhingidae, Burhinidae, Recurvirostridae, Turnicidae, Laridae, Tytonidae, Bucerotidae, Upupidae, Ramphastidae, Coraciidae, Pittidae, Oriolidae, Vangidae, Aegithinidae, Monarchidae, Paridae, Zosteropidae, Timaliidae with one species (RDI= 0.54) each respectively (Table 2). A similar pattern of dominance of Accipitridae was observed by different authors from different protected areas in India, i.e., from Araku Valley of Ananthagiri Hills of the Eastern Ghats in Visakhapatnam, Andhra Pradesh (Kumar et al. 2010), a scrub forest of Sri Lankamalleswara Wildlife Sanctuary, Andhra Pradesh (Mali et al. 2017), Tamhini Wildlife Sanctuary, the northern Western Ghats, Maharashtra (Vinayak & Mali 2018), and Bhimbandh Wildlife Sanctuary, Bihar (Khan & Pant 2017).

Avian community structure as per residential status and relative abundance

The analysis of data on the residential status revealed that out of 189 species, 140 (74%) were resident, 44 (23%) winter, 3 (2%) summer, and 2 (1%) passage migrants respectively (Figure 2). The occurrence of a significant number of winter migrant species can be attributed partly to the study area being on the Central Asian Flyway and serving as a wintering and stopover site for migratory birds that breed in the Palearctic region

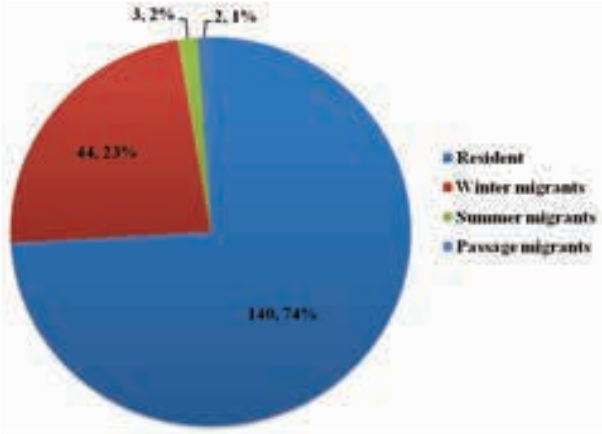

Figure 2. Residential status (%) of birds at Daroji Sloth Bear Sanctuary.

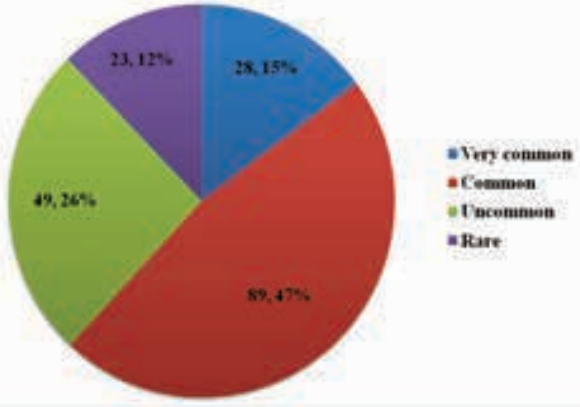

Figure 3. Relative abundance (%) of birds at Daroji Sloth Bear Sanctuary.

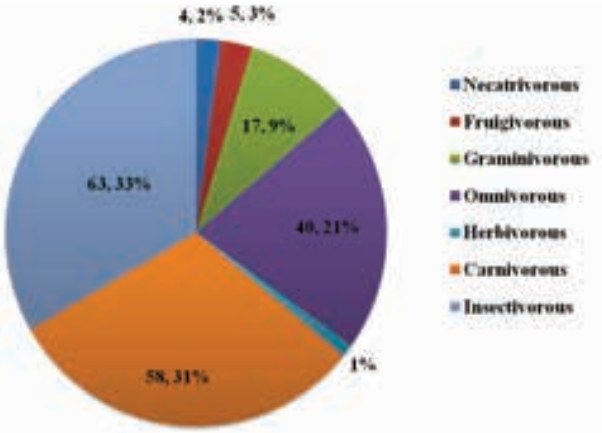

Figure 4. Feeding guilds (%) of birds at Daroji Sloth Bear Sanctuary.

(Kumar et al. 2016). The spatio-temporal distribution and relative abundance of avifauna in any given habitat are determined based on the quality and quantity of food available as the major factor (Wiens 1989; Ma et

Table 1. Systematic list and status of Birds in Daroji Sloth Bear Sanctuary, Karnataka.

	Common name	Scientific name	Feeding guilds	Residential status	Relative abundance	IUCN	WPA
	Order: Anseriformes						
	Family: Anatidae						
1	Lesser Whistling Duck	*Dendrocygna javanica* Horsfield, 1821	O	R	Co	LC	Sch. IV
2	Garganey	*Spatula querquedula* Linnaeus, 1758	H	Wm	Ra	LC	Sch. IV
3	Northern Shoveler	*Spatula clypeata* Linnaeus, 1758	C	Wm	Ra	LC	Sch. IV
4	Indian Spot-billed Duck	*Anas poecilorhyncha* J.R. Forster, 1781	H	R	Co	LC	Sch. IV
5	Northern Pintail	*Anas acuta* Linnaeus, 1758	C	Wm	Ra	LC	Sch. IV
	Order: Galliformes						
	Family: Phasianidae						
6	Rain Quail	*Coturnix coromandelica* J.F. Gmelin, 1789	G	R	Co	LC	Sch. IV
7	Jungle Bush Quail	*Perdicula asiatica* Latham, 1790	G	R	Vc	LC	Sch. IV
8	Rock Bush Quail	*Perdicula argoondah* Sykes, 1832	G	R	Vc	LC	Sch. IV
9	Grey Francolin	*Francolinus pondicerianus* J.F. Gmelin, 1789	G	R	Vc	LC	Sch. IV
10	Painted Spurfowl	*Galloperdix lunulata* Valenciennes, 1825	O	R	Vc	LC	Sch. IV
11	Indian Peafowl	*Pavo cristatus* Linnaeus, 1758	O	R	Vc	LC	Sch. I
	Order: Phoenicopteriformes						
	Family: Podicipitidae						
12	Little Grebe	*Tachybaptus ruficollis* Pallas, 1764	C	R	Co	LC	Sch. IV
	Order: Columbiformes						
	Family: Columbidae						
13	Rock Pigeon	*Columba livia* J.F. Gmelin, 1789	G	R	Vc	LC	Sch. IV
14	Spotted Dove	*Streptopelia chinensis* Scopoli, 1786	G	R	Vc	LC	Sch. IV
15	Eurasian Collared Dove	*Streptopelia decaocto* Frivaldszky, 1838	G	R	Vc	LC	Sch. IV
16	Laughing Dove	*Streptopelia senegalensis* Linnaeus, 1766	G	R	Vc	LC	Sch. IV
17	Red Collared Dove	*Streptopelia tranquebarica* Hermann, 1804	G	R	Co	LC	Sch. IV
	Order: **Pterocliformes**						
	Family: **Pteroclidae**						
18	Chestnut-bellied Sandgrouse	*Pterocles exustus* Temminck, 1825	G	R	Co	LC	Sch. IV
19	Painted Sandgrouse	*Pterocles indicus* J.F. Gmelin, 1789	G	R	Co	LC	Sch. IV
	Order: Caprimulgiformes						
	Family: Caprimulgidae						
20	Indian Nightjar	*Caprimulgus* asiaticus Latham, 1790	I	R	UC	LC	Sch. IV
	Family: Apodidae						
21	Indian House Swift	*Apus affinis* J.E. Gray, 1830	I	R	VC	LC	Sch. IV
22	Asian Palm Swift	*Cypsiurus balasiensis* J.E. Gray, 1829	I	R	Co	LC	Sch. IV
	Order: Cuculiformes						
	Family: Cuculidae						
23	Asian Koel	*Eudynamys scolopaceus* Linnaeus, 1758	F	R	Co	LC	Sch. IV
24	Greater Coucal	*Centropus sinensis* Stephens, 1815	O	R	Co	LC	Sch. IV
25	Blue-faced Malkoha	*Phaenicophaeus viridirostris* Jerdon, 1840	O	R	Co	LC	Sch. IV
26	Common Hawk Cuckoo	*Hierococcyx varius* Vahl, 1797	I	R	Co	LC	Sch. IV
27	Sirkeer Malkoha	*Taccocua leschenaultia* Lesson, 1830	I	R	Uc	LC	Sch. IV
28	Crested Pied Cuckoo	*Clamator jacobinus* Boddaert, 1783	I	Sm	Uc	LC	Sch. IV
29	Grey-bellied Cuckoo	*Cacomantis passerinus* Vahl, 1797	I	R	Uc	LC	Sch. IV

	Common name	Scientific name	Feeding guilds	Residential status	Relative abundance	IUCN	WPA
	Order: Gruiformes						
	Family: Rallidae						
30	Common Coot	*Fulica atra* Linnaeus, 1758	O	R	Co	LC	Sch. IV
31	White-breasted Waterhen	*Amaurornis phoenicurus* Pennant, 1769	O	R	Co	LC	Sch. IV
32	Slaty-breasted Rail	*Lewinia striata* Linnaeus, 1766	O	R	Uc	LC	Sch. IV
33	Brown Crake	*Zapornia akool* Sykes, 1832	O	R	Co	LC	Sch. IV
34	Purple Swamphen	*Porphyrio porphyrio* Linnaeus, 1758	O	R	Co	LC	Sch. IV
	Order: Pelecaniformes						
	Family: Ciconiidae						
35	Painted Stork	*Mycteria leucocephala* Pennant, 1769	C	R	Ra	NT	Sch. IV
36	Woolly-necked Stork	*Ciconia episcopus* Boddaert, 1783	C	R	Co	VU	Sch. IV
37	Asian Openbill	*Anastomus oscitans* Boddaert, 1783	C	R	Co	LC	Sch. IV
	Family: Ardeidae						
38	Little Egret	*Egretta garzetta* Linnaeus, 1766	C	R	Vc	LC	Sch. IV
39	Intermediate Egret	*Ardea intermedia* Wagler, 1829	C	R	Co	LC	Sch. IV
40	Cattle Egret	*Bubulcus ibis* Linnaeus, 1758	C	R	Vc	LC	Sch. IV
41	Great Egret	*Ardea alba* Linnaeus, 1758	C	R	Co	LC	Sch. IV
42	Indian Pond Heron	*Ardeola grayii* Sykes, 1832	C	R	Vc	LC	Sch. IV
43	Striated Heron	*Butorides striata* Linnaeus, 1758	C	R	Co	LC	Sch. IV
44	Grey Heron	*Ardea cinerea* Linnaeus, 1758	C	Pm	Co	LC	Sch. IV
45	Purple Heron	*Ardea purpurea* Linnaeus, 1766	C	R	Co	LC	Sch. IV
	Family: Threskiornithidae						
46	Black-headed Ibis	*Threskiornis melanocephalus* Latham, 1790	C	R	Co	NT	Sch. IV
47	Indian Black Ibis	*Pseudibis papillosa* Temminck, 1824	C	R	Co	LC	Sch. IV
	Family: Phalacrocoracidae						
48	Little Cormorant	*Microcarbo niger* Vieillot, 1817	C	R	Co	LC	Sch. IV
49	Indian Cormorant	*Phalacrocorax fuscicollis* Stephens, 1826	C	R	Co	LC	Sch. IV
50	Great Cormorant	*Phalacrocorax carbo Linnaeus, 1758*	C	R	Co	LC	Sch. IV
	Family: Anhingidae						
51	Oriental Darter	*Anhinga melanogaster* Pennant, 1769	C	R	Co	NT	Sch. IV
	Order: Charadriiformes						
	Family: Burhinidae						
52	Indian Thick-knee	*Burhinus oedicnemus* Linnaeus, 1758	C	R	Uc	LC	Sch. IV
	Family: Charadriidae						
53	Yellow-wattled Lapwing	*Vanellus malabaricus* Boddaert, 1783	C	R	Uc	LC	Sch. IV
54	Red-wattled Lapwing	*Vanellus indicus* Boddaert, 1783	C	R	Co	LC	Sch. IV
55	Little Ringed Plover	*Charadrius dubius* Scopoli, 1786	C	Wm	Uc	LC	Sch. IV
	Family: Recurvirostridae						
56	Black-winged Stilt	*Himantopus himantopus* Linnaeus, 1758	C	Wm	Uc	LC	Sch. IV
	Family: Jacanidae						
57	Bronze-winged Jacana	*Metopidius indicus* Latham, 1790	C	R	Co	LC	Sch. IV
58	Pheasant-tailed jacana	*Hydrophasianus chirurgus* Scopoli, 1786	C	R	Co	LC	Sch. IV
	Family: Scolopacidae						
59	Little Stint	*Calidris minuta* Leisler, 1812	C	Wm	Uc	LC	Sch. IV
60	Wood Sandpiper	*Tringa glareola* Linnaeus, 1758	C	Wm	Uc	LC	Sch. IV
61	Common Snipe	*Gallinago gallinago* Linnaeus, 1758	C	Wm	Uc	LC	Sch. IV

	Common name	Scientific name	Feeding guilds	Residential status	Relative abundance	IUCN	WPA
62	Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	C	Wm	Uc	LC	Sch. IV
63	Marsh Sandpiper	*Tringa stagnatilis* Bechstein, 1803	C	Wm	Uc	LC	Sch. IV
64	Green Sandpiper	Tringa ochropus Linnaeus, 1758	C	Wm	Uc	LC	Sch. IV
	Family: Turnicidae						
65	Barred Buttonquail	*Turnix suscitator* J.F. Gmelin, 1789	C	R	Co	LC	Sch. IV
	Family: Laridae						
66	River Tern	*Sterna aurantia* J.E. Gray, 1831	C	R	Co	NT	Sch. IV
	Order: Accipitriformes						
	Family: Accipitridae						
67	Oriental Honey Buzzard	*Pernis ptilorhynchus* Temminck, 1821	C	R	Uc	LC	Sch. I
68	Black-winged Kite	*Elanus caeruleus* Desfontaines, 1789	C	R	Co	LC	Sch. I
69	Short-toed Snake Eagle	*Circaetus gallicus* J.F. Gmelin, 1788	C	R	Uc	LC	Sch. I
70	Shikra	*Accipiter badius* J.F. Gmelin, 1788	C	R	Co	LC	Sch. I
71	Black Eagle	*Ictinaetus malaiensis* Temminck, 1822	C	R	Uc	LC	Sch. I
72	Booted Eagle	*Hieraaetus pennatus* J.F. Gmelin, 1788	C	Wm	Uc	LC	Sch. I
73	Bonelli's Eagle	*Aquila fasciata* vieillot, 1822	C	R	Co	LC	Sch. I
74	Pallid Harrier	*Circus macrourus* S.G. Gmelin, 1770	C	Wm	Ra	NT	Sch. I
75	Western Marsh Harrier	*Circus aeruginosus* Linnaeus, 1758	C	Wm	Uc	LC	Sch. I
76	Montagu's Harrier	*Circus pygargus* Linnaeus, 1758	C	Wm	Ra	LC	Sch. I
77	Black Kite	*Milvus migrans* Boddaert, 1783	C	R	Co	LC	Sch. I
78	Brahminy Kite	*Haliastur Indus* Boddaert, 1783	C	R	Co	LC	Sch. I
	Order: Strigiformes						
	Family: Tytonidae						
79	Barn Owl	*Tyto alba* Scopoli, 1769	C	R	Co	LC	Sch. IV
	Family: Strigidae						
80	Indian Eagle Owl	*Bubo bengalensis* Franklin, 1831	C	R	Co	LC	Sch. IV
81	Brown Fish Owl	*Ketupa zeylonensis* J.F. Gmelin, 1788	C	R	Co	LC	Sch. IV
82	Spotted Owlet	*Athene brama* Temminck, 1821	C	R	Co	LC	Sch. IV
	Order: Bucerotiformes						
	Family: Bucerotidae						
83	Indian Grey Hornbill	*Ocyceros birostris* Scopoli, 1786	F	R	Uc	LC	Sch. I
	Family: Upupidae						
84	Common Hoopoe	*Upupa epops* Linnaeus, 1758	I	R	Co	LC	Sch. IV
	Order: Piciformes						
	Family: Picidae						
85	Eurasian Wryneck	*Jynx torquilla* Linnaeus, 1758	I	Wm	Ra	LC	Sch. IV
86	Yellow-crowned Woodpecker	*Dendrocopos mahrattensis* Latham, 1801	I	R	Co	LC	Sch. IV
87	Lesser Golden-blacked Woodpecker	*Dinopium benghalense* Linnaeus, 1758	I	R	Co	LC	Sch. IV
	Family: **Ramphastidae**						
88	Coppersmith Barbet	*Psilopogon haemacephalus* Muller, 1776	F	R	Co	LC	Sch. IV
	Order: Coraciiformes						
	Family: Meropidae						
89	Green Bee-eater	*Merops orientalis* Latham, 1801	I	R	Vc	LC	Sch. IV
90	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus, 1767	I	Wm	Uc	LC	Sch. IV
	Family: Coraciidae						
91	Indian Roller	*Coracias benghalensis* Linnaeus, 1758	C	R	Co	LC	Sch. IV

	Common name	Scientific name	Feeding guilds	Residential status	Relative abundance	IUCN	WPA
	Family: Alcedinidae						
92	Common Kingfisher	*Alcedo atthis* Linnaeus, 1758	C	R	Co	LC	Sch. IV
93	White-throated Kingfisher	*Halcyon smyrnensis* Linnaeus, 1758	C	R	Co	LC	Sch. IV
94	Pied Kingfisher	*Ceryle rudis* Linnaeus, 1758	C	R	Co	LC	Sch. IV
	Order: Falconiformes						
	Family: Falconidae						
95	Common Kestrel	*Falco tinnunculus* Linnaeus, 1758	C	Wm	Uc	LC	Sch. IV
96	Peregrine Falcon	*Falco peregrinus* Tunstall, 1771	C	Wm	Uc	LC	Sch. I
	Order: Psittaciformes						
	Family: Psittaculidae						
97	Rose-ringed Parakeet	*Psittacula krameri* Scopoli, 1769	F	R	Vc	LC	Sch. IV
98	Plum-headed Parakeet	*Psittacula cyanocephala* Linnaeus, 1766	F	R	Uc	LC	Sch. IV
	Order: Passeriformes						
	Family: Pittidae						
99	Indian Pitta	*Pitta brachyuran* Linnaeus, 1766	I	Sm	Ra	LC	Sch. IV
	Family: Campephagidae						
100	Black-headed Cuckooshrike	*Lalage melanoptera* Ruppell, 1839	I	R	Uc	LC	Sch. IV
101	Small Minivet	*Pericrocotus cinnamomeus* Linnaeus, 1766	I	R	Uc	LC	Sch. IV
	Family: Oriolidae						
102	Indian Golden Oriole	*Oriolus kundoo* Sykes, 1832	O	Sm	Co	LC	Sch. IV
	Family: Vangidae						
103	Common Woodshrike	*Tephrodornis pondicerianus* J.F. Gmelin, 1789	I	R	Co	LC	Sch. IV
	Family: Aegithinidae						
104	Common Iora	*Aegithina tiphia* Linnaeus, 1758	I	R	Co	LC	Sch. IV
	Family: Dicruridae						
105	Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	O	R	Co	LC	Sch. IV
106	White-bellied Drongo	*Dicrurus caerulescens* Linnaeus, 1758	O	R	Uc	LC	Sch. IV
107	Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817	O	Wm	Uc	LC	Sch. IV
	Family: Laniidae						
108	Brown Shrike	*Lanius cristatus* Linnaeus, 1758	I	Wm	Uc	LC	Sch. IV
109	Long-tailed Shrike	*Lanius schach* Linnaeus, 1758	I	R	Co	LC	Sch. IV
110	Bay-backed Shrike	*Lanius vittaus* Valenciennes, 1826	I	R	Co	LC	Sch. IV
111	Southern Grey Shrike	*Lanius excubitor* Linnaeus, 1758	C	R	Co	LC	Sch. IV
	Family: Corvidae						
112	Rufous Treepie	*Dendrocitta vagabunda* Latham, 1790	O	R	Co	LC	Sch. IV
113	House Crow	*Corvus splendens* Vieillot, 1817	O	R	Co	LC	Sch. IV
114	Jungle Crow	*Corvus macrorhynchos* Wagler, 1827	O	R	Co	LC	Sch. IV
	Family: Monarchidae						
115	Indian Paradise Flycatcher	*Terpsiphone paradise* Linnaeus, 1758	I	R	Co	LC	Sch. IV
	Family: Dicaeidae						
116	Pale-billed Flowerpecker	*Dicaeum erythrorynchos* Latham, 1790	N	R	Co	LC	Sch. IV
117	Thick-billed Flowerpecker	*Dicaeum agile* Tickell, 1833	N	R	Co	LC	Sch. IV
	Family: Nectariniidae						
118	Purple-rumped Sunbird	*Leptocoma zeylonica* Linnaeus, 1766	N	R	Vc	LC	Sch. IV
119	Purple Sunbird	*Cinnyris asiaticus* Latham, 1790	N	R	Vc	LC	Sch. IV

	Common name	Scientific name	Feeding guilds	Residential status	Relative abundance	IUCN	WPA
	Family: Ploceidae						
120	Baya Weaver	*Ploceus philippinus* Linnaeus, 1766	G	R	Vc	LC	Sch. IV
121	Streaked Weaver	*Ploceus manyar* Horsfield, 1821	G	R	Uc	LC	Sch. IV
	Family: Estrildidae						
122	Red Avadavat	*Amandava amandava* Linnaeus, 1758	G	R	Uc	LC	Sch. IV
123	Indian Silverbill	*Euodice malabarica* Linnaeus, 1758	G	R	Vc	LC	Sch. IV
124	Black-headed Munia	*Lonchura Malacca* Linnaeus, 1766	G	R	Co	LC	Sch. IV
125	Scaly-breasted Munia	*Lonchura punctulata* Linnaeus, 1758	G	R	Vc	LC	Sch. IV
	Family: Passeridae						
126	House Sparrow	*Passer domesticus* Linnaeus, 1758	O	R	Vc	LC	Sch. IV
127	Yellow-throated Sparrow	*Gymnoris xanthocollis* E. Burton, 1838	O	R	Uc	LC	Sch. IV
	Family: Motacillidae						
128	White-browed Wagtail	*Motacilla maderaspatensis* J.F. Gmelin, 1789	I	R	Co	LC	Sch. IV
129	Western Yellow Wagtail	*Motacilla flava* Linnaeus, 1758	I	Wm	Uc	LC	Sch. IV
130	Grey Wagtail	*Motacilla cinerea* Tunstall, 1771	I	Wm	Uc	LC	Sch. IV
131	White Wagtail	*Motacilla alba* Linnaeus, 1758	I	Wm	Uc	LC	Sch. IV
132	Paddyfield Pipit	*Anthus rufulus* Vieillot, 1818	I	R	Uc	LC	Sch. IV
	Family: Emberizidae						
133	Red-headed Bunting	*Granativora bruniceps* von Brandt, 1841	I	Wm	Ra	LC	Sch. IV
134	Black-headed Bunting	*Granativora melanocephala* Scopoli, 1769	I	Wm	Ra	LC	Sch. IV
135	Grey-necked Bunting	*Emberiza buchanani* Blyth, 1845	I	Wm	Ra	LC	Sch. IV
	Family: Paridae						
136	Cinereous (Great) Tit	*Parus cinereus* Vieillot, 1818	I	R	Co	LC	Sch. IV
	Family: Alaudidae						
137	Ashy-crowned Sparrow Lark	*Eremopterix grisea* Scopoli, 1786	I	R	Vc	LC	Sch. IV
138	Singing Bushlark	*Mirafra cantillans* Blyth, 1845	O	R	Co	LC	Sch. IV
139	Sykes's Lark	*Galerida deva* Sykes, 1832	O	R	Co	LC	Sch. IV
140	Crested Lark	*Galerida cristata* Linnaeus, 1758	O	R	Co	LC	Sch. IV
141	Jerdon's Bushlark	*Mirafra affinis* Blyth, 1845	O	R	Co	LC	Sch. IV
142	Oriental Skylark	*Alauda gulgula* Franklin, 1831	O	Wm	Uc	LC	Sch. IV
143	Indian Bushlark	*Mirafra erythroptera* Blyth, 1845	O	R	Co	LC	Sch. IV
144	Rufous-tailed Finch Lark	*Ammomanes phoenicura* Franklin, 1831	O	R	Co	LC	Sch. IV
	Family: Cisticolidae						
145	Zitting Cisticola	*Cisticola juncidis* Rafinesque, 1810	I	R	Uc	LC	Sch. IV
146	Grey-breasted Prinia	*Prinia hodgsonii* Blyth, 1844	I	R	Co	LC	Sch. IV
147	Ashy Prinia	*Prinia socialis* Sykes, 1832	I	R	Co	LC	Sch. IV
148	Plain Prinia	*Prinia inornata* Sykes, 1832	I	R	Co	LC	Sch. IV
149	Jungle Prinia	*Prinia sylvatica* Jerdon, 1840	I	R	Co	LC	Sch. IV
150	Common Tailorbird	*Orthotomus sutorius* Pennant, 1769	I	R	Co	LC	Sch. IV
	Family: Acrocephalidae						
151	Blyth's Reed Warbler	*Acrocephalus dumetorum* Blyth, 1849	I	Wm	Ra	LC	Sch. IV
152	Clamorous Reed Warbler	*Acrocephalus stentoreus* Hemprich & Ehrenberg, 1833	I	R	Ra	LC	Sch. IV
153	Booted Warbler	*Iduna caligata* M.H.C. Lichtenstein, 1823	I	Wm	Ra	LC	Sch. IV
	Family: Hirundinidae						
154	Dusky Crag Martin	*Ptyonoprogne concolor* Sykes, 1832	I	R	Vc	LC	Sch. IV

	Common name	Scientific name	Feeding guilds	Residential status	Relative abundance	IUCN	WPA
155	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	I	Wm	Ra	LC	Sch. IV
156	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	I	R	Co	LC	Sch. IV
157	Red-rumped Swallow	*Cecropis daurica* Laxmann, 1769	I	R	Ra	LC	Sch. IV
158	Streak-throated Swallow	*Petrochelidon fluvicola* Blyth, 1855	I	R	Ra	LC	Sch. IV
	Family: Pycnonotidae						
159	Red-whiskered Bulbul	*Pycnonotus jucosus* Linnaeus, 1758	O	R	Vc	LC	Sch. IV
160	Red-vented Bulbul	*Pycnonotus cafer* Linnaeus, 1766	O	R	Vc	LC	Sch. IV
161	White-browed Bulbul	*Pycnonotus luteolus* Lesson, 1841	O	R	Co	LC	Sch. IV
162	Yellow-throated Bulbul	*Pycnonotus xantholaemus* Jerdon, 1845	O	R	Uc	VU	Sch. IV
	Family: Phylloscopidae						
163	Greenish Leaf Warbler	*Seicercus trochiloides* Sundevall, 1837	I	Wm	Ra	LC	Sch. IV
164	Tickell's leaf warbler	*Phylloscopus affinis* Tickell, 1833	I	Wm	Ra	LC	Sch. IV
165	Green Leaf Warbler	*Seicercus nitidus* Blyth, 1843	I	Pm	Ra	LC	Sch. IV
	Family: Sylviidae						
166	Yellow-eyed Babbler	*Chrysomma sinense* J.F. Gmelin, 1789	I	R	Co	LC	Sch. IV
167	Hume's (Lesser) Whitethroat	*Curruca curruca* Linnaeus, 1758	I	Wm	Ra	LC	Sch. IV
	Family Zosteropidae						
168	Oriental White-eye	*Zosterops palpebrosus* Temminck, 1824	I	R	Uc	LC	Sch. IV
	Family: Timaliidae						
169	Tawny-bellied babbler	*Dumetia hyperythra* Franklin, 1831	O	R	Uc	LC	Sch. IV
	Family: Leiothrichidae						
170	Common Babbler	*Argya caudata* Dumont, 1823	O	R	Co	LC	Sch. IV
171	Jungle Babbler	*Turdoides striata* Dumont, 1823	O	R	Vc	LC	Sch. IV
172	Large Grey Babbler	*Argya malcolmi* Sykes, 1832	O	R	Vc	LC	Sch. IV
173	Yellow-billed Babbler	*Turdoides affinis* Jerdon, 1845	O	R	Vc	LC	Sch. IV
	Family: **Sturnidae**						
174	Chestnut-tailed Starling	*Sturnia malabarica* J.F. Gmelin, 1789	O	Wm	Uc	LC	Sch. IV
175	Brahminy Starling	*Sturnia pagodarum* J.F. Gmelin, 1789	O	R	Co	LC	Sch. IV
176	Common Myna	*Acridotheres tristis* Linnaeus, 1766	O	R	Co	LC	Sch. IV
177	Jungle Myna	*Acridotheres fuscus* Wagler, 1827	O	R	Co	LC	Sch. IV
178	Rosy Starling	*Pastor roseus* Linnaeus, 1758	O	Wm	Uc	LC	Sch. IV
	Family: Muscicapidae						
179	Bluethroat	*Luscinia svecica* Linnaeus, 1758	I	Wm	Ra	LC	Sch. IV
180	Indian Robin	*Saxicoloides fulicatus* Linnaeus, 1766	I	R	Co	LC	Sch. IV
181	Oriental Magpie Robin	*Copsychus saularis* Linnaeus, 1758	I	R	Co	LC	Sch. IV
182	Asian Brown Flycatcher	*Muscicapa dauurica* Pallas, 1811	I	Wm	Ra	LC	Sch. IV
183	Tickell's Blue Flycatcher	*Cyornis tickelliae* Blyth, 1843	I	R	Co	LC	Sch. IV
184	Verditer Flycatcher	*Eumyias thalassinus* Swainson, 1838	I	Wm	Uc	LC	Sch. IV
185	Red-breasted Flycatcher	*Ficedula parva* Bechstein, 1792	I	Wm	Uc	LC	Sch. IV
186	Black Redstart	*Phoenicurus ochruros* S.G. Gmelin, 1774	I	Wm	Uc	LC	Sch. IV
187	Blue Rock Thrush	*Monticola solitarius* Linnaeus, 1758	I	Wm	Uc	LC	Sch. IV
188	Pied Bushchat	*Saxicola caprata* Linnaeus, 1766	I	R	Co	LC	Sch. IV
189	Siberian Stonechat	*Saxicola maurus* Pallas, 1773	I	Wm	Uc	LC	Sch. IV

IUCN Red List categories: LC—Least Concern | NT—Near Threatened | VU—Vulnerable | WPA Schedules (I, II, III, IV) as per Indian Wildlife (Protection) Act, 1972 | Residential Status: R—Resident | Wm—Winter migrant | Sm—Summer migrant | Pm—Passage migrant | Feeding guilds: I—Insectivorous | C—Carnivorous | H—Herbivorous | O—Omnivorous | G—Granivorous | F—Frugivorous | N—Nectarivorous | Relative Abundance: Co—Common | Uc—Uncommon | Vc—Very common | Ra—Rare.

Table 2. Relative diversity index (RDI) of various avian families at Daroji Sloth Bear Sanctuary, Karnataka.

	Family	No. of species	RDI
1	Accipitridae	12	6.45
	Muscicapidae	11	5.91
2	Ardeidae Alaudidae	8	4.30
3	Cuculidae	7	3.76
4	Phasianidae Scolopacidae Cisticolidae	6	3.23
5	Anatidae Columbidae Motacillidae Hirundinidae Sturnidae Rallidae	5	2.69
6	Laniidae Estrildidae Pycnonotidae Leiothrichidae	4	2.15
7	Ciconiidae Phalacrocoracidae Charadriidae Strigidae Picidae Alcedinidae Corvidae Emberizidae Acrocephalidae Phylloscopidae	3	1.61
8	Pteroclidae Apodidae Threskiornithidae Jacanidae Meropidae Falconidae Psittaculidae Campephagidae Dicruridae Dicaeidae Nectariniidae Ploceidae Passeridae Sylviidae	2	1.08
9	Podicipitidae Caprimulgidae Anhingidae Burhinidae Recurvirostridae Turnicidae Laridae Tytonidae Bucerotidae Upupidae Ramphastidae Coraciidae Pittidae Oriolidae Vangidae Aegithinidae Monarchidae Paridae Zosteropidae Timaliidae	1	0.54

al. 2010; Jha 2013). The analysis of relative abundance based on the frequency of sightings indicated that 89 species were common, 49 were uncommon, 28 were very common and 23 were rare species, which accounts for 47%, 26%, 15%, and 12% of the frequency of distribution in the study area (Figure 3).

Avian community structure as per habitat

From the earlier studies undertaken elsewhere, it is evident that variation in vegetation structure influences species distribution (MacArthur et al., 1962; Karr & Roth, 1971; Pearman 2002) within a habitat. Of the 189 species recorded, 139 species were associated with terrestrial habitat and 50 species were wetland-associated, which account for 74% and 26% of total bird species recorded (Table 1). Wetland characteristics like size, water depth, quality of water, trophic structure, and presence of suitable roosting and nursery sites influence the abundance and diversity of birds (Wiens 1989; Mukherjee et al. 2002; Ma et al. 2010). During the present study, wetland birds such as ducks, herons, egrets, cormorants, grebes, storks, jacanas, and kingfishers, which were observed to feed on aquatic organisms (fish, amphibians, invertebrates, etc.,) at different water depths available in the wetlands and adjoining agriculture fields and marshy area.

Feeding guild structure

The diversity of avifauna in the study area may be due to the presence of a wide spectrum of food niches. The different species of birds occupying a particular feeding guild and space have evolved specialized foraging strategies to explore and obtain food resources efficiently and thus to reduce competition among diverse species (Nudds & Bowlby 1984; Jose & Zacharias 2003). An analysis of the feeding guilds of these birds revealed that 33% (63 species) were insectivorous and 31% (58 species) were carnivorous, 21% (40 species) were omnivorous, 9% (17 species) were granivorous, 3% (5 species) were frugivorous, 2% (4 species) were nectarivorous and 1% (2 species) were herbivorous respectively (Figure 3). Due to their specialized diet and low availability of preferable food resources, the nectarivores and piscivores are traditionally less represented (Wiens 1989). Occurrence of a significant number of insectivorous bird communities indicates that the area consists rich insect diversity as well as less disturbance in the form of forest fire consequences (Gregory et al. 2001) and also play a major role as important bio-control agents of insect pest of agriculture, horticulture, and forest ecosystem (Mahabal 2005; Thakur et al. 2010).

Among the 21 species of birds of prey recorded from the study area, 17 species were diurnal raptors like Oriental Honey Buzzard *Pernis ptilorhynchus*, Black-

Images 3, 4 & 5 Anthropogenic activities in Daroji Sloth Bear Sanctuary. © K.S. Abdul Samad

winged Kite *Elanus caeruleus*, Short-toed Snake Eagle *Circaetus gallicus*, Shikra *Accipiter badius*, Black Eagle *Ictinaetus malaiensis*, Booted Eagle *Hieraaetus pennatus*, Bonelli's Eagle *Aquila fasciata*, Pallid Harrier *Circus macrourus*, Western Marsh Harrier *Circus aeruginosus*, Montagu's Harrier *Circus pygargus*, Black Kite *Milvus migrans*, Brahminy Kite *Haliastur indus*, Common Kestrel *Falco tinnunculus*, and Peregrine Falcon *Falco peregrines* and the other four were nocturnal raptors like Barn Owl *Tyto alba*, Indian Eagle Owl *Bubo bengalensis*, Brown Fish Owl *Ketupa zeylonensis*, and Spotted Owlet *Athene brama***.** The presence of carnivorous species in the study area, which is primarily influenced by the availability of food sources, however, indicates the abundance of their prey. Prey bases such as small birds, lizards, snakes, rats, are among the food sources for carnivores in the area. The study area also supports four species of nectarivorous birds which include, Thick-billed Flowerpecker *Dicaeum agile*, Pale-billed Flowerpecker *Dicaeum erythrorynchos*, Purple-rumped Sunbird *Leptocoma zeylonica*, and Purple Sunbird *Cinnyris asiaticus* have been regularly seen from the area.

Conservation status of avian fauna

To understand the importance of a site it is necessary to examine the significance in terms of the presence and abundance of species (Bruford 2002). DSBS supports 15 (8%) species of birds included in Schedule I, and 174 (92%) species included in Schedule IV of the Wildlife Protection Act (WPA, 1972). As per IUCN red list, Daroji supports, two globally Vulnerable (VU) species—Yellow-throated Bulbul *Pycnonotus xantholaemus* & Woolly-necked Stork *Ciconia episcopus*—five Near Threatened (NT) species—Painted Stork *Mycteria leucocephala,* Black-headed Ibis *Threskiornis melanocephalus,* Oriental Darter *Anhinga melanogaster,* River Tern *Sterna aurantia*, & Pallid Harrier *Circus macrourus* (IUCN, 2010)—and remaining 180 species are under Least Concern (LC) (Table 1).

It is evident from earlier studies that the landscape with diverse habitats provides opportunities for diverse avian fauna assemblages (Karr & Roth 1971). The study area has been selected as an important bird area in India (IBA), as it maintains a significant thriving population of a globally threatened and vulnerable species, i.e., Yellow-throated Bulbul with its fragmented population is restricted to the southern Deccan Plateau of India (Birdlife International 2001). Earlier recorded sighting (Allen 1908) of 20 pairs was in June 1901 in the Ballari District. Kottur (2014) observed this species around Matanga Hill in Hampi, Daroji Sloth Bear Sanctuary, and Sannapura Forest in the Koppal District. This species has been considered as Vulnerable because of threats caused due to degradation of its scrub forest habitats by various anthropogenic activities such as total clearance of vegetation, excessive wood-cutting, cattle-grazing and the quarrying of hillocks, etc (Subramanya et al. 1993, 1995; Stattersfield et al. 1998).

Daroji Sloth Bear Sanctuary lies in an important bio-geographic zone, i.e., Deccan Peninsula with its amazingly diverse vegetation structure and environments not only attracts a variety of resident as well as migratory bird species but also influence their diversity and distribution within the habitat (MacArthur et al. 1962; Karr & Roth 1971; Pearman 2002). Anthropogenic disturbances on

forest structure and function are well on record (Bhat & Murali 2001; Chandrashekara et al. 2006) and indicated a negative influence of the anthropogenic intervention on overall bird diversity (Image 3–5). The present study also revealed that the avifauna and their habitat was under threats due to intensive anthropogenic activities, highlighted earlier along with those other disturbances like habitat alternations, construction of roads, firewood collection, and poaching in the forest areas that impacted the environment adversely which intern disturbing many threatened and migratory bird species. Hence, documentation of the bird community and identification of potential threats are the primary concerns of conservation at present.

The data recorded in the present study provides valuable information about the diversity of avifauna of Daroji Sloth Bear Sanctuary, as a baseline data for future EIA studies, and helping in formulating future conservation strategies to improve the forest habitats, which will attract the number of the resident bird as well as migratory species. Further, more long-term scientific studies and monitoring along with local participation needed to understand the ecological status, seasonal wise abundance, and diversity, and conservation of birds in this particular area.

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COMMUNICATION

Birds of Surat-Dangs: a consolidated checklist of 75 years (1944–2020) with special emphasis on noteworthy bird records and bird hotspots from northern Western Ghats of Gujarat, India

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Abstract: Surat-Dangs, historically known as a Bhil State, is the northernmost tip of Western Ghats in the state of Gujarat. Despite being a part of an endemic bird area and global biodiversity hotspot, avifaunal diversity has been less documented in the landscape. Two protected areas, Purna Wildlife Sanctuary and Vansda National Park, are designated in the landscape. A handful of studies on birds have been conducted after Dr. Salim Ali's collection in 1944–48. We surveyed the landscape (both protected and non-protected areas) in 2012–13 and 2015–2018 for documentation of the avifaunal diversity. We present a consolidated checklist of birds from our surveys as primary data and all published literature and eBird checklists as secondary data. We have reported a total of 297 bird species belonging to 70 families and 21 orders including the first record of Nilgiri Wood-Pigeon *Columba elphinstonii* for the State as well as Purna Wildlife Sanctuary. Here, we have re-reported various species, which was suspected to be locally extinct from the protected area or landscape among other noteworthy bird records. We have identified bird-rich localities outside the protected areas based on the survey done by Salim Ali (1944–48) that can be used for future surveys. We also propose the landscape to be declared as an Important Bird Area (IBA) as per Global IBA criteria (A1, A2, & A3), which will pave the milestone for future conservation endeavors in the landscape.

Keywords: Avian diversity, eBird, Important Bird Area, Gujarat Forest Department, Nilgiri Wood-Pigeon.

Gujarati abstract: સુરત-ડાંગ્સ, જે ઐતહિાસકિ રીતે ભીલ રાજ્ય તરીકે જાણીતો છે તે ગુજરાત રાજ્યમાં પશ્ચમિ ઘાટનો ઉત્તરીય ભાગ છે. સ્થાનકિ પક્ષી ક્ષેત્ર અને વૈશ્વકિ જૈવવવિધિતા હોટસ્પોટનો ભાગ હોવા છતાં, આ વસ્તિારના પક્ષીવૈવધિ્ય વષિ ઘણી ઓછી માહતિી ઉપલબ્ધ છે. આ વસ્તિારમાં પૂરણા વન્યપ્રાણી અભયારણ્ય અને વાંસદા રાષ્ટ્રીય ઉદ્યાન એ બે આરક્ષતિ ક્ષેત્ર ઘોષતિ કરવામાં આવ્યા છે. ૧૯૪૪-૪૮ દરમયિાન ડૉ. સલીમ અલીના સંગ્રહ પછી પક્ષીઓ પર થોડા ઘણાં સંશોધનો કરવામાં આવ્યા છે. ૨૦૧૨—૧૩ અને ૨૦૧૫—૨૦૧૮માં પક્ષીવૈવધિ્યની નોંધ કરવા માટે, અમે આ વસ્તિારનું (બંને, આરક્ષતિ અને બનિ- આરક્ષતિ) સર્વેક્ષણ કર્યું હતું. અમે અમારા સર્વે દરમયિાન નોંધેલા પક્ષીઓને પ્રાથમકિ માહતિી અને અન્ય પ્રકાશતિ સાહત્યિ અને ઇ-બર્ડ ચેકલસ્ટિ્સનો ગૌણ માહતિી તરીકે ઉપયોગ કરીને એક એકીકૃત ચેકલસ્ટિ્ ૨જૂ કરીએ છીએ. અમે ૭૦ ફેમલિી અને ૨૧ ઑર્ડરમાં વર્ગીકૃત કુલ ૨૯૭ પક્ષીઓની પ્રજાતઓિની નોંધ કરી છે, જેમાં રાજ્ય અને પૂરણા વન્યપ્રાણી અભયારણ્ય માટે નીલગરિવિુડ-પીજન કોલંબા ઍલ્ફન્સિ્ટોનીની પ્રથમ નોંધ છે. અન્ય નોંધપાત્ર પક્ષીઓની નોંધ ઉપરાંત અહીં અમે એવા અમુક પક્ષીઓની પણ નોંધ કરી છે જેમની આરક્ષતિ વસ્તિાર અથવા આ વસ્તિારમાંથી સ્થાનકિ રીતે લુપ્ત થવાની આશંકા હતી. અમે ડૉ. સલીમ અલી (૧૯૪૪-૪૮) દ્વારા કરેલા સર્વેક્ષણના આધારે, આરક્ષતિ ક્ષેત્રોની બહાર પક્ષીઓથી સમૃદ્ધ વસ્તિારોની ઓળખ કરી છે, જેનો ઉપયોગ ભવષ્યિના સર્વેક્ષણ માટે થઇ શકે છે. અમે આ વસ્તિારને વૈશ્વકિ આઇબીએ માપદંડ (એ૧, એ૨, અને એ૩) મુજબ મહત્વના પક્ષી વસ્તિાર (આઇબીએ) તરીકે ઘોષતિ કરવાની પણ દરખાસ્ત કરી છે, જેનાથી વસ્તિારમાં ભાવસિંરક્ષણ પ્રયત્નો માટેનો પાયો બંધાશે.

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INTRODUCTION

Gujarat State occupies the northern extremity of the western seaboard of India. Its natural ecosystems range from marine and wetlands to deserts, grasslands, moist deciduous forests, and a coastline of 1,650km, with two gulfs (Gulf of Khambhat and Gulf of Kachchh), the longest in India. The State is home to nearly 582 species of birds (Ganpule 2017). Gujarat falls on the Indus Flyway that makes it an important place on the ornithological map of India (Jambu 2013).

The Dangs District (20.550–21.083 ^{0}N, 73.450–73.950 ^{0}E; 105–1,317 m; 1,764km^{2}) lies in the southern part of Gujarat State bordering Maharashtra. It forms the northernmost tip of the Western Ghats (hereafter referred to as WG) and is endowed with closed-canopy forest with trees of 30m height or more. WG has been identified as a global biodiversity hotspot and endemic bird area (Stattersfield et al. 1998; Myers et al. 2000); however, only a few avifaunal studies have been undertaken in the Dangs District in the past (Ali 1954–55; Shull 1962; Worah 1991; Singh et al. 2000; Trivedi 2003).

The landscape starts from the rugged mountain chains of Sahyadri Hills in the east and descends in the west to the plains of Gujarat. Most of the region of the Dangs District is endowed with hilly terrain. With elevation ranging from 105m in the west to 1,317m in the eastern border, with some hills in the east and south, the region is chained with a series of flat-topped low hills. Along with forest patches in Surat District, the landscape was noted as "Surat-Dangs", a tribal country since British time. The Dangs District is divided mainly into four valleys of Gira, Purna, Khapri, and Ambika rivers, arising from the hills and flowing down towards the west into the Arabian Sea. These are perennial rivers retaining some water even in the dry hot summer season.

Forests of the Dangs are known to be the richest in diversity and density in Gujarat State. The district has a forest cover of 77.16%, with 440–550 plant species, of which, 120 species are medicinal and economically valuable timber species (Jain 1963; Patel 1971; Shah & Yadav 1979; Singh et al. 2000; Kumar et al. 2007). Two protected areas (hereafter referred to as PAs) designated in the Surat-Dangs landscape are Purna Wildlife Sanctuary (160km^{2}) (hereafter referred to as PWS) and Vansda National Park (24km^{2}) (hereafter referred to as VNP, Image 1). The entire forest area of the VNP falls under the following subtypes: 3B/C2 southern moist mixed deciduous forest, 5/E9 dry bamboo brakes, 5/IS1 tropical riverine forest (Champion & Seth 1968). The PWS forest is under eight sub-types: 3B/C1 a very moist teak forest, 3B/C1b moist teak forest, 3B/C1c slightly moist teak forest, 3B/C2 southern moist mixed deciduous forest, 5A/C1b dry teak forests, 5A/C3 dry mixed deciduous forests, 5E9 dry bamboo brakes, and 5/IS1 dry tropical riverine forest (Champion & Seth 1968).

Dangs forest has a long history of timber exploitation and systematic forestry since 1840 (Worah 1991), and selective felling had eliminated almost all large trees (mostly teak with a girth of 90cm) since 1897 (Khanchandani 1970). In addition, forestry operations of thinning and climber-cutting remove lianas as well as several species of low timber value associated with teak (Anonymous 2001). Worah (1991) had documented the negative impact of forest fragmentation on the avian community in the Dangs forests. In Dangs, mass flowering of *Bambusa arudinacea* (Retz.) Willd., a species widespread in the area, happened in 2007. Owing to its ecology, all the bamboos dried up post-flowering, forest fires became frequent. Hence, as per bamboo management, harvesting license was given for three years. During these years, most of the bamboo in the sanctuary was harvested, altering the habitat into an open and sparse forest (Jambu 2013).

After the bamboo flowering of 2007 and subsequent harvesting, a 30-day survey, spanning various months and seasons of the year (2012–2013), was done by Nikunj Jambu (hereafter referred to as NJ) in PWS and surrounding areas to document the avifaunal species present therein. After the survey, various sporadic field trips were made by NJ and Kaushal Patel (hereafter referred to as KP) covering various localities of Dangs District. Another year-long survey was carried out by NJ and KP during 2015–2016, covering various regions of the district, with special focus on PWS. A vulture census was also carried out in April 2016, in collaboration with the local forest department, to estimate the vulture population in the Gadad region of Dangs. For the endangered and endemic species, Forest Owlet, KP carried out special status and distribution surveys in 2015–2016 in the district. Also, a citizen science initiative called Dangs Bird Festival (hereafter referred to as DBF) was initiated by NJ and KP in collaboration with the local forest department for three consecutive years from 2016 to 2018. Data collected through DBFs is also mentioned here. Lastly, previous surveys by Ali (1954–1955), Shull (1962), Worah (1991), Singh et al. (2000), Trivedi (2003), earlier published records, reports and eBird sightings are incorporated here to prepare a consolidated checklist of the last 75 years (1944–2020).

METHODS

The methodology used (for example, direct sightings, call recording, call playback, survey timings) for bird surveys were different with different time series. These are mentioned in detailed year-wise descriptions in the following section.

NJ surveyed 18 different trails across PWS in winter and summer seasons from December 2012 to April 2013 (referred to as NJ 2012–2013), multiple times, both during day and evening, once each between 06.45–10.00 h and 16.00–18.45 h. The trails were selected in such a way that different types of habitats are covered. Call playback and call recording methods were not used during this study period. Ad libitum data collection was also done at random locations in PWS. Also, different habitats were thoroughly and intensively surveyed for selective bird species.

During the study of 2015–2016, we surveyed 23 random trails, covering various habitats (dense forest, open forest, moist deciduous forest, dry deciduous forest, mixed deciduous forest, agricultural fields near the edge of the PA boundary) of PWS. These trails were covered in winter and summer seasons during day and evening times. Call play-back method and opportunistic surveys were done to cover reserve forests and agricultural fields, in addition to the PAs, in the Dangs District (referred to as NJ and KP 2015–16). The call play-back method was used to identify nocturnal bird species (owlets, owls and nightjars). Pre-recorded calls were obtained from www.xeno-canto.org/asia for use in call play-back method in locations where the species were expected to occur.

As a part of a citizen science and outreach program, during DBF, the participants were divided into five teams and each team walked different forest trails varying 2–8 km to cover all the types of habitats in and around the PWS. Volunteers and forest staff also accompanied each team on all three days at 06.30–11.00 h. All the sightings were verified by volunteers as well as confirmed with the bird photographs taken during the walk. DBF was conducted for three consecutive years: 5–7 February 2016, 3–5 February 2017 and 9–11 February 2018. No call play-back, call recording or nocturnal surveys were done during these events (referred to as DBF 2016, DBF 2017, and DBF 2018).

For the confirmation records of the Forest Owlet, KP used the knowledge of locals. KP conducted interviews using both audio and visual clues. Confirmation was further made by playing pre-recorded call of the species. Calls were played from October 2015 to May 2016, known to be its breeding season (Mehta et al. 2008). The species is vocal during this season and easy to detect using the call play-back method. As the species is diurnal, the call was played in the morning (07.00–11.00 h) and afternoon (13.00–18.00 h) in teak-dominated open dry-deciduous forests or seasonal agricultural fields. After selecting a site, the pre-recorded call was broadcast for 1 minute, followed by 5 minutes of pause. The presence/absence record of the species was confirmed by direct sighting, call response, or both by visiting all 111 sites thrice.

A census (total count) of *Gyps indicus* (Long-billed Vulture) was carried out on 2 and 3 April 2016 at Gadad Village, Piplai Devi range by NJ and KP, in collaboration with the forest department - North Dangs division, Ahwa. Around 20 volunteers accompanied with the forest department staff participated in this activity.

eBird (www.ebird.org) is an online platform, where bird-watchers around the world share their sightings and checklists. Verified data from such open-source platforms is used as secondary data by many researchers in preparing consolidated checklists. We have also incorporated certain eBird checklists from seasoned birders in our consolidated checklist (Referred to as eBird- The Dangs County, Gujarat India and Vansda NP).

Finally, data collected by the authors (NJ 2012–13, NJ and KP 2015–16, DBF 2016, DBF 2017, and DBF 2018) as primary data and previous bird surveys (Ali (1954–1955), Shull (1962), Worah (1991), Singh et al. (2000), Trivedi (2003), ebird records, and other published article on new bird sightings from the landscape) as secondary data are incorporated in preparing a consolidated checklist for the last 75 years (1944–48 to 2020) from Surat-Dangs landscape. Lastly, bird hotspots and localities have been identified from the surveys done by Ali (1954–55) and Shull (1962).

RESULTS

In total 297 species (Table 1, Figure 1) belonging to 21 orders and 70 families (Figure 2) has been recorded from the Surat-Dangs landscape representing 51.03% of the avifauna recorded from the Gujarat State (Ganpule 2017) and 22.85% of India's Bird species (Rahmani et al. 2016). Both the protected areas are home to 77.44 % (PWS) and 65.32 % (VNP) of the 297 species recorded from the district. The high diversity could be due to intense alterations in habitat fidelity over the past 125 years (1897–2020). Local Dangi names for some of the bird species have also been provided here.

Order Passeriformes dominated the avifauna with

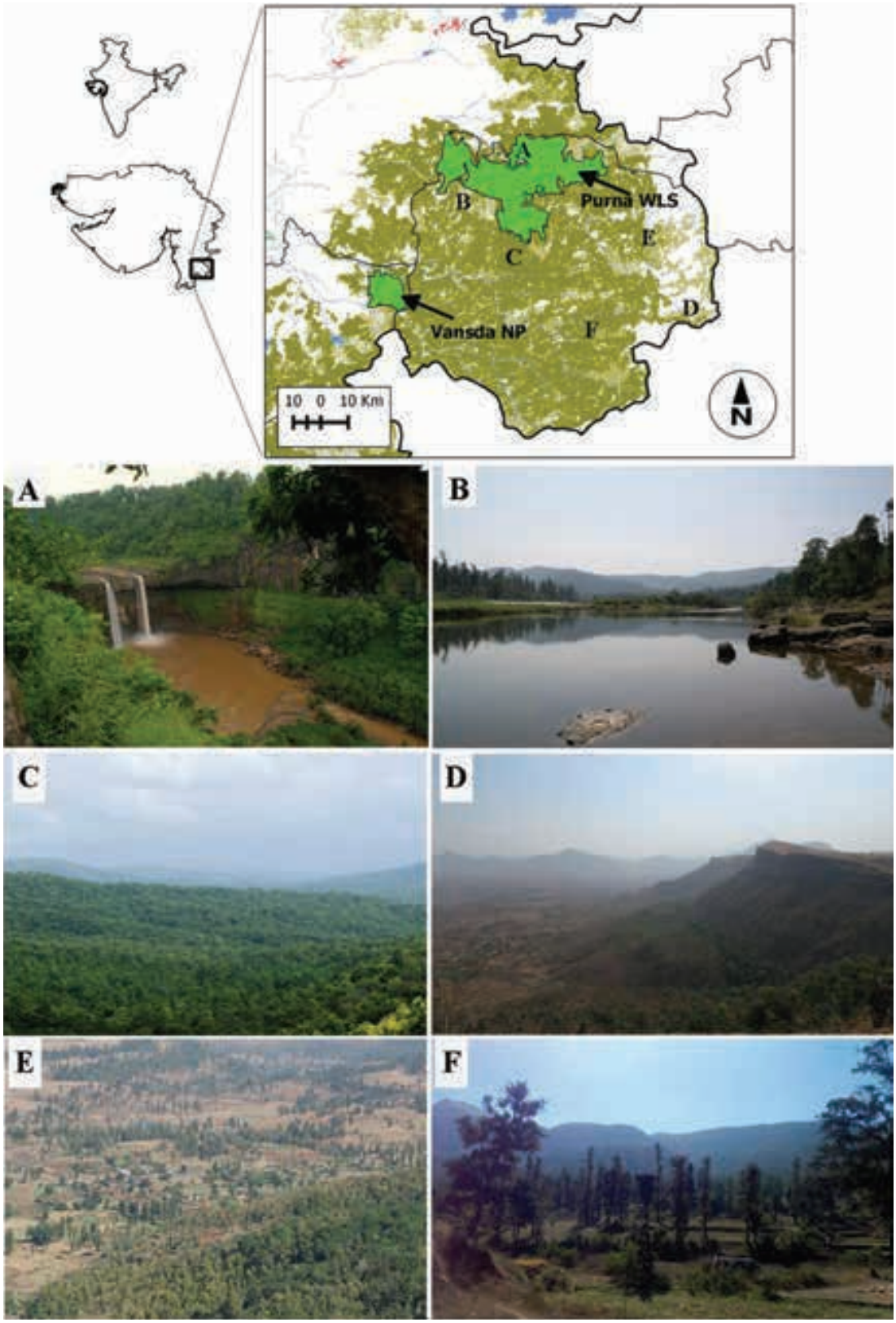

Image 1. Map of the study area with different habitat types: A—Gira waterfall, a riverine – moist deciduous forest system at Gira River, near Girmal Village | B—Riverine mixed deciduous forest system at Purna River, near Bheshkarti Village | C—Mixed deciduous (high canopy forest) Purna WS | D—Don hill chains flat plateau on the top and unique wild mango forest in the valley, near Gadad Village | E—Top view of forest edge with village and agriculture complex | F—Open teak dominated dry deciduous forest and agriculture field. (D- Don hills- Vulture nesting sites, F- One of the Forest Owlet positive sites) (© A,B,C,F—Kaushal Patel | © D,E—Parul Bhatnagar).

141 species belonging to 37 families (see Figure 2). Family Accipitridae exhibited the highest richness with 25 species, followed by Muscicapidae and Strigidae with 18 and 13 species, respectively. The birds of Surat-Dangs belong to seven basic foraging guilds (Figure 3). Insectivores (133 spp, 44.78 %) dominated the birds' assemblages followed by carnivores (45 spp, 15.15%) and omnivores (48 spp, 16.16%); 42 species (14.14%) are aquatic; granivore (15 spp, 5.05%), frugivore (11 spp, 3.70%), and nectarivore (3 spp, 1.01%) are least represented (Figure 3). We have re-reported the following species: Red Spurfowl *Galloperdix spadicea* (J.F. Gmelin, 1789), Jungle Bush Quail *Perdicula asiatica* (Latham, 1790), White-spotted Fantail *Rhipidura* (*albicollis*) *albogularis* (Lesson, 1832), and Indian Yellow Tit *Parus* (*xanthogenys*) *aplonotus* (Blyth, 1847), which were suspected to be locally extinct from PWS (Trivedi & Soni 2006).

Nineteen species fall under various categories as per the IUCN Red List. Seven species were categorized as Near Threatened, seven Vulnerable, two each Critically Endangered and Endangered, while one as Data Deficient (Table 2). Record of WG endemic Nilgiri Wood Pigeon *Columba elphinstonii* (Sykes, 1832) from Surat-Dangs is an addition to the bird list of the State. Surat-Dangs is home to four range-restricted species to WG (15.38%, 4 out of 26) and one range-restricted species (Forest Owlet *Athene blewitti*) to central Indian forests (Rehmani et al. 2016), 17 country endemic birds (22.67%, 17 out of 75) (Birdlife International 2020) and 49 Biome restricted species (AS07 Sino-Himalayan Temperate Forest- 1 out of 183= 0.55%, AS08 Sino-Himalayan temperate forest- 1 out of 169= 0.59%, AS10 Indian peninsula tropical moist forest: 8 out of 55= 14.54%, Indio-Malayan tropical dry zone- 37 out of 78= 47.44%, AS13 Saharo-Sindian desert- 2 out of 20= 10%) (Chan et al. 2004) (See Table 2 for details).

Probable first record for Gujarat State

Nilgiri Wood-Pigeon *Columba elphinstonii* (Sykes, 1832)

On 3 March 2016, during a forest walk in conservation plot (a part of PWS), KP observed a bird similar to Turtle Dove on a teak tree of about 15m height. After close inspection with binocular (Steiner Predator Pro 8×42), KP observed that the bird had darker maroon-brown under-parts, darker under-wing and uniform slate-grey tail, a black and white chequered pattern on the hindneck and purple-green gloss on the mantle, foreneck and breast. After a thorough inspection, the individual was identified to be a WG endemic *Columba elphinstonii* (Nilgiri Wood Pigeon), normally found in moist deciduous and shola forests (Grimmett et al. 2014). It is listed under the 'Vulnerable' category by IUCN (Birdlife International 2017a). This is probably the first record from PWS and Gujarat State, as the species has not been listed in the 'Birds of Gujarat State Checklist' by Ganpule (2016). The species can be confused with the common and similar appearing species of Turtle Dove and thereby could be easily ignored. The closest record of this species is from the adjoining Nashik District in Maharashtra (Gaidhani 2019). KP was not able to photograph the individual, owing to not having a camera, but had satisfactorily confirmed the species using binocular and Grimmett et al. (2014) as the field guide. The species could be a rare resident in the landscape. Further surveys are required to understand the population status and distribution of this species in Surat-Dangs.

Noteworthy first records from the Surat-Dangs forests

Western Reef-Egret *Egretta gularis* (Bosc, 1792)

Western Reef-Egret *Egretta gularis* is usually found around seashores, estuaries, mangroves and tidal creeks, but occasionally in freshwater (Grimmett et al. 2014). One of the team spotted an individual during the DBF 2016 in a river near Duldha Village on 7 February 2016. This sighting record from Dangs is more than 100km away from the nearest coastline. NJ and KP photographed and reconfirmed the sighting, along with five other members of the DBF at the same location on 8 February 2016.

Taiga Flycatcher *Ficedula albicilla* (Pallas, 1811)

Taiga Flycatcher *Ficedula albicilla* can be easily mistaken with the recently split subspecies Red-breasted Flycatcher *F. Parva* (Rasmussen & Anderton 2005). It is a winter migrant to India and its distribution is mainly in northeastern, eastern, and central India, the Eastern Ghats (hereafter referred to as EG) reaching up to western Maharashtra and Goa (Rasmussen & Anderton 2005; Grimmett et al. 2014). No sightings were recorded from Gujarat State until 2011 from the Saurashtra region (Ganpule 2013). On 13 January 2013, NJ photographed the species in PWS from a trail near the Mahal campsite. Records in 2014, 2017, and 2018 from PWS during the winter suggest that the Taiga Flycatcher is a common winter visitor in Dangs forests. Apart from Dangs, the species has been recorded from Gir NP, Sagai, Rajpipla, Morbi, Rajkot, Thol WS, and Girnar WS from October to March in the state (Ganpule 2014a).

Large-tailed Nightjar *Caprimulgus macrurus* Horsfield, 1821

On 6 April 2013, after surveying the trail in

Table 1. Consolidated checklist of the birds of Surat-Dangs over 75 years (1944–2020).
Data set: 1—Ali S. (1954–55) & Shull (1962) | 2—Worah (1991) | 3—Singh et al. (2000) | 4—Trivedi (2003) | 5—NJ (2012–2013) | 6—NJ & KP (2015–2016) | 7—DBF 2016 | 8—DBF 2017 | 9—DBF 2018 | 10—eBird sightings | 11—Published Articles
Published article: A—Jat (2015) | B—Patel et al. (2017) | C—Maheria et al. (2018) | D—Patel (2017a) | E—McMaster A.S. (1871) | F—Bharti (2017) .
Guild: C—Carnivore | AQ—Aquatic | I—Insectivore | F—Frugivore | O—Omnivore | G—Granivore | N—Nectarivore
Habitat Preference: FIS—Forest-Interior Species | FES—Forest-Edge Sepcies | IES—Interior-Edge Species (used by Worah (1991) for her study)
IUCN Status: LC—Least Concern | DD—Data Deficient | NT—Near Threatened | VU—Vulnerable | EN—Endangered | CR—Critically Endangered
Local Status: R—Resident | WV—Winter Visitor | MV—Monsoon Visitor | PV—Passage Visitor | SV—Summer Visitor | VAG—Vagrant | UNK—Unknown
Note: we have followed Praveen et al. (2020) for nomenclature. (Exceptions: We have considered Black-eared Kite *Milvus lineatus* and Black Kite *Milvus migrans*, Barbary Falcon *Falco* (*peregrinus*) *pelegrinoides* and Peregrine Falcon *Falco peregrinus,* Hume's Whitethroat *Sylvia althaea* and Lesser Whitethroat *Sylvia curruca* as separate species.)

Common name	Scientific name	Guild	Local name	Habitat preference	IUCN Status	Local status	1	2	3	4	5	6	7	8	9	10	11
Order Accipitriformes																	
Family Accipitridae																	
Shikra	*Accipiter badius*	C	Shashina	FIS	LC	R	+	+	+	+	+	+	+	+	+	+	
Eurasian Sparrowhawk	*Accipiter nisus*	C			LC	WV	+	-	-	-	-	-	-	-	+	+	
Greater Spotted Eagle	*Clanga clanga*	C			VU	WV	-	-	-	-	-	+	-	-	-	-	
Bonelli's Eagle	*Aquila fasciata*	C			LC	R	-	-	-	-	-	+	-	-	+	+	
Tawny Eagle	*Aquila rapax*	C			VU	R	+	-	-	+	-	-	-	-	-	-	
White-eyed Buzzard	*Butastur teesa*	C			LC	R	+	-	-	+	+	+	+	-	+	+	
Common Buzzard	*Buteo buteo*	C			LC	WV	-	-	-	-	-	-	-	-	-	+	
Long-legged Buzzard	*Buteo rufinus*	C			LC	WV	-	-	-	-	-	+	-	-	-	+	
Short-toed Snake Eagle	*Circaetus gallicus*	C			LC	R	+	+	-	-	+	+	-	+	-	+	
Eastern Marsh Harrier	*Circus spilonotus*	C			LC	WV	+	-	-	-	-	-	-	-	-	-	
Pallid Harrier	*Circus macrourus*	C			NT	WV	+	+	-	-	-	-	-	-	-	+	
Montagu's Harrier	*Circus pygargus*	C			LC	WV	+	-	-	-	-	-	-	-	-	+	
Black-winged Kite	*Elanus caeruleus*	C			LC	R	+	+	-	+	+	+	+	+	-	+	
White-rumped Vulture	*Gyps bengalensis*	C	Gidh		CR	R	+	+	+	+	+	-	-	-	-	+	
Indian Vulture	*Gyps indicus*	C	Gidh		CR	R	+	-	-	+	-	+	-	-	-	+	
Brahminy Kite	*Haliastur indus*	C			LC	R	+	-	-	-	+	-	-	-	-	-	
Booted Eagle	*Hieraaetus pennatus*	C			LC	WV	-	-	-	-	-	+	-	-	-	+	
Grey-Headed Fish Eagle	*Haliaeetus ichthyaetus*	C			NT	R	-	-	-	-	+	-	-	-	-	-	
Black Eagle	*Ictinaetus malaiensis*	C			LC	R	-	-	-	+	+	-	-	-	-	-	
Black-eared Kite	*Milvus lineatus*	C	Shamdi		LC	WV	-	-	-	-	-	-	-	-	+	-	
Black Kite	*Milvus migrans*	C	Shamdi		LC	R	+	+	+	-	+	-	-	+	-	+	
Egyptian Vulture	*Neophron percnopterus*	C			EN	R	+	-	-	-	-	-	-	-	-	-	
Crested Hawk Eagle	*Nisaetus cirrhatus*	C			LC	R	+	-	-	-	-	+	-	+	-	+	
Oriental Honey-Buzzard	*Pernis ptilorhynchus*	C	Madhiyo/ Duggho		LC	R	+	+	-	+	+	+	+	+	+	+	
Crested Serpent Eagle	*Spilornis cheela*	C	Kokhi	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Order Anseriformes																	
Family Anatidae																	
Common Teal	*Anas crecca*	AQ			LC	WV	-	-	-	-	-	-	+	-	-	+	

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Indian Spot-billed Duck	*Anas poecilorhyncha*	AQ	Batak		LC	R	-	-	-	-	-	-	+	-	-	+	
Lesser Whistling Duck	*Dendrocygna javanica*	AQ	Batak		LC	R	-	-	-	-	+	-	-	-	-	-	
Knob-billed Duck	*Sarkidiornis melanotos*	AQ			LC	R	-	-	-	-	-	-	-	-	-	+	
Order Apodiformes																	
Family Apodidae																	
Indian House Swift	*Apus affinis*	I	Abholi		LC	R	-	+	-	-	-	-	-	+	-	+	
Asian Palm Swift	*Cypsiurus balasiensis*	I	Abholi		LC	R	-	+	+	-	-	-	-	+	-	+	
Alpine Swift	*Tachymarptis melba*	I	Abholi		LC	R	+	-	-	+	+	-	-	+	-	+	
Family Hemiprocnidae																	
Crested Treeswift	*Hemiprocne coronata*	I			LC	R	+	+	+	+	+	+	+	-	-	+	
Order Bucerotiformes																	
Family Bucerotidae																	
Indian Grey Hornbill	*Ocyceros birostris*	F	Bhenas	FIS	LC	R	+	+	+	+	+	+	+	-	+	+	
family Upupidae																	
Common Hoopoe	*Upupa epops*	I	Sagarfani		LC	R	-	-	+	+	+	+	-	-	+	+	
Order Caprimulgiformes																	
Family Caprimulgidae																	
Indian Nightjar	*Caprimulgus asiaticus*	I			LC	R	-	-	+	+	-	+	-	+	-	+	
Jungle Nightjar	*Caprimulgus indicus*	I	Taapu		LC	R	+	+	-	+	-	+	-	-	-	-	
Large-tailed Nightjar	*Caprimulgus macrurus*	I			LC	R	-	-	-	-	+	-	-	-	-	+	
Syke's Nightjar	*caprimulgus mahrattensis*	I			LC	R	-	-	-	-	-	-	-	-	-	+	
Order Charadriiformes																	
Family Burhinidae																	
Indian Thick-Knee	*Burhinus indicus*	I			LC	R	+	-	-	-	-	-	-	-	-	+	
Great Thick-knee	*Esacus recurvirostris*	I			NT	R	-	-	-	-	-	-	-	-	-	+	
Family Charadriidae																	
Red-wattled Lapwing	*Vanellus indicus*	AQ	Titodi		LC	R	-	-	+	+	+	+	+	+	-	+	
Yellow-wattled Lapwing	*Vanellus malabaricus*	AQ	Titodi		LC	R	-	-	-	-	-	-	-	-	-	+	
Family Laridae																	
Gull-billed Tern	*Gelochelidon nilotica*	AQ			LC	WV	-	-	-	-	-	+	-	-	-	-	
River Tern	*Sterna aurantia*	AQ			NT	R	-	-	-	-	-	+	-	-	-	+	
Family Recurvirostridae																	
Black-winged Stilt	*Himantopus himantopus*	AQ			LC	R	-	+	-	-	-	+	-	-	-	+	
Family Scolopacidae																	
Common Sandpiper	*Actitis hypoleucos*	AQ	Titodi	IES	LC	WV	-	+	+	+	+	+	+	+	+	+	
Wood Sandpiper	*Tringa glareola*	AQ	Titodi		LC	WV	-	-	-	-	-	-	-	+	-	+	
Common Greenshank	*Tringa nebularia*	AQ			LC	WV	-	-	-	-	-	-	-	+	-	+	
Green Sandpiper	*Tringa ochropus*	AQ	Titodi		LC	WV	+	+	+	+	+	-	-	+	-	+	

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Marsh Sandpiper	*Tringa stagnatilis*	AQ	Titodi		LC	WV	-	-	-	-	+	-	-	+	-	+	
Common Redshank	*Tringa totanus*	AQ			LC	WV	-	-	-	-	-	-	-	+	-	+	
Family Turnicidae																	
Barred Buttonquail	*Turnix suscitator*	O			LC	R	-	-	-	+	+	+	-	-	-	-	
Order Ciconiiformes																	
Family Ciconiidae																	
Asian Openbill	*Anastomus oscitans*	AQ			LC	R	-	-	-	-	-	+	-	+	-	+	
European White Stork	*Ciconia ciconia*	AQ			LC	WV	+	-	-	-	-	-	-	-	-	-	
Wolly-necked Stork	*Ciconia episcopus*	AQ			VU	R	+	+	-	-	-	-	-	-	-	-	
Painted Stork	*Mycteria leucocephala*	AQ			NT	WV	+	-	-	-	-	-	-	-	-	-	
Order Columbiformes																	
Family Columbidae																	
Asian Emerald Dove	*Chalcophaps indica*	F	Nir/Nil holo	FIS	LC	R	+	+	-	+	+	+	-	+	+	+	
Nilgiri Wood Pigeon	*Columba elphinstonii*	F			VU	R	-	-	-	-	-	+	-	-	-	-	
Rock Pigeon	*Columba livia*	G	Pareva		LC	R	+	+	-	+	+	+	+	-	-	+	
Spotted Dove	*Streptopelia chinensis*	G	Holi	IES	LC	R	+	+	+	+	+	+	+	-	+	+	
Laughing Dove	*Streptopelia senegalensis*	G	Hasti Holi	FES	LC	R	-	+	+	-	+	+	+	-	+	+	
Eurasian Collared Dove	*Streptopelia decaocto*	G	Holi		LC	R	-	-	+	+	-	+	-	+	+	+	
Oriental Turtle Dove	*Streptopelia orientalis*	G	Holi		LC	WV	+	+	-	+	+	+	-	+	-	+	
Red Collared Dove	*Streptopelia tranquebarica*	G	Holi		LC	R	-	-	-	-	+	-	+	+	-	+	
Grey-fronted Green Pigeon	*Treron affinis*	F		FIS	LC	R	-	-	+	-	-	-	-	-	-	-	
Yellow-footed Green Pigeon	*Treron phoenicopterus*	F	Halid/Harod	FIS	LC	R	+	+	+	+	+	+	+	-	+	+	
Order Coraciiformes																	
Family Alcedinidae																	
Common Kingfisher	*Alcedo atthis*	AQ	Dhindha		LC	R	-	+	-	+	+	+	+	+	+	+	
Pied Kingfisher	*Ceryle rudis*	C	Dhindhla		LC	R	-	-	+	-	+	-	-	+	-	+	
Oriental Dwarf Kingfisher	*Ceyx erithaca*	AQ	Dhindhla		LC	MV	-	-	-	-	-	-	-	-	-	-	A
Black-capped Kingfisher	*Halcyon pileata*	AQ			LC	R	+	-	-	-	-	-	-	-	-	+	
White-throated Kingfisher	*Halcyon smyrnensis*	AQ	Dhindhla	FES	LC	R	-	+	+	+	+	+	+	+	+	+	
Stork-billed Kingfisher	*Pelargopsis capensis*	AQ			LC	R	+	-	-	-	-	-	-	-	-	-	
Family Coraciidae																	
Indian Roller	*Coracias benghalensis*	I	Tashliyo	FES	LC	R	+	+	-	+	+	+	+	-	+	+	
Eurasian Roller	*Coracias garrulus*	I		FES	LC	PV	-	-	-	-	-	+	-	-	-	+	
Family Meropidae																	
Green Bee-eater	*Merops orientalis*	I	Pirvit	FES	LC	R	+	+	+	+	+	+	+	+	+	+	
Blue-cheeked Bee-eater	*Merops persicus*	I	Pirvit		LC	PV	-	-	-	-	-	-	-	-	-	+	
Blue-tailed Bee-eater	*Merops philippinus*	I	Pirvit		LC	PV	-	-	+	-	-	-	-	-	-	+	
Blue-bearded Bee-eater	*Nyctyornis athertoni*	I			LC	R	+	-	-	-	-	-	-	-	-	-	

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Order Cuculiformes																	
Family Cuculidae																	
Grey-bellied Cuckoo	*Cacomantis passerinus*	I			LC	SV	-	-	-	-	-	-	+	-	-	+	
Banded Bay cuckoo	*Cacomantis sonneratii*	I			LC	R	+	-	-	-	-	-	-	-	-	+	
Greater Coucal	*Centropus sinensis*	C	Kakad Kumbhariyo	IES	LC	R	+	+	-	+	+	+	+	+	+	-	
Pied Cuckoo	*Clamator jacobinus*	I			LC	SV	-	-	+	-	-	+	+	-	-	-	
Indian Cuckoo	*Cuculus micropterus*	I		FIS	LC	SV	+	+	+	+	-	-	-	-	+	+	
Lesser Cuckoo	*Cuculus poliocephalus*	I			LC	PV	+	-	-	-	-	-	-	-	-	-	
Asian Koel	*Eudynamys scolopaceus*	O	Kohoo	IES	LC	R	-	+	+	+	+	+	-	+	-	+	
Common Hawk Cuckoo	*Hierococcyx varius*	I	Pipida	IES	LC	R	+	+	+	+	+	+	-	+	-	+	
Blue-faced Malkoha	*Phaenicophaeus viridirostris*	I			LC	R	-	-	-	-	-	-	+	-	-	-	
Fork-Tailed Drongo Cuckoo	*Surniculus dicruroides*	I			LC	SV	-	-	-	-	-	-	-	-	-	+	
Sqaure-tailed Drongo Cuckoo	*Surniculus lugubris*	I			LC	SV	-	-	+	-	-	-	-	-	-	-	
Sirkeer Malkoha	*Taccocua leschenaultii*	I			LC	R	+	-	+	-	-	-	-	-	-	+	
Order Falconiformes																	
Family Falconidae																	
Amur Falcon	**Falco amurensis**	C			LC	PV	-	-	-	-	-	-	-	-	-	+	
Barbary Falcon	*Falco (peregrinus) pelegrinoides*	C			LC	WV	-	-	-	-	-	+	-	-	-	-	
Peregrine Falcon	*Falco peregrinus*	C			LC	R	-	-	-	-	+	+	+	-	-	+	
Eurasian Hobby	*Falco subbuteo*	C			LC	WV	-	+	-	+	-	+	-	-	-	-	
Common Kestrel	*Falco tinnunculus*	C			LC	WV	-	+	-	+	+	+	-	-	-	+	
Order Galliformes																	
Family Phasianidae																	
Blue-breasted Quail	*Synoicus chinensis*	G			LC	R	-	-	-	-	-	-	-	-	-	-	B
Common Quail	*Coturnix coturnix*	G	Lavri		LC	WV	+	-	-	-	-	-	-	-	-	-	
Painted Francolin	*Francolinus pictus*	G	Titar	FES	LC	R	+	+	+	+	-	+	-	-	-	+	
Grey Francolin	*Francolinus pondicerianus*	G			LC	R	-	-	-	-	-	-	-	+	-	+	
Red Spurfowl	*Galloperdix spadicea*	O	Jungli Mardho/ Kukdo	FIS	LC	R	+	+	+	-	-	+	-	-	-	+	
Red Junglefowl	*Gallus gallus*	O	Jungli Mardho/ Kukdo	FIS	LC	R	-	-	-	-	-	+	-	-	-	+	
Grey Junglefowl	*Gallus sonneratii*	O	Jungli Mardho/ Kukdo	FIS	LC	R	+	+	+	+	+	+	-	-	+	+	
Indian Peafowl	*Pavo cristatus*	O	Mor	FIS	LC	R	+	+	+	+	+	+	-	+	+	+	
Jungle Bush Quail	*Perdicula asiatica*	G		IES	LC	R	+	+	+	-	-	-	-	-	-	+	
Order Gruiformes																	
Family Gruidae																	
Sarus Crane	*Antigone antigone*	O			VU	WV	-	-	-	-	-	-	-	-	-	+	
Common Crane	*Grus grus*	O	Karkucha		LC	WV	-	-	-	-	-	-	-	-	-	+	
Demoiselle Crane	*Grus virgo*	O			LC	WV	-	-	-	-	+	+	-	-	-	-	

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Family Rallidae																	
White-breasted Waterhen	*Amaurornis phoenicurus*	AQ	Kuwa		LC	R	+	+	+	+	-	-	-	+	+	+	
Eurasian Coot	*Fulica atra*	AQ			LC	R	-	-	-	-	+	+	-	-	-	-	
Order Passeriformes																	
Family Acrocephalidae																	
Byth's Reed Warbler	*Acrocephalus dumetorum*	I			LC	WV	+	-	-	-	-	+	-	-	-	+	
Large-billed Reed Warbler	*Acrocephalus orinus*	I			DD	PV	-	-	-	-	-	-	-	-	-	-	C
Clamorous Reed Warbler	*Acrocephalus stentoreus*	I			LC	WV	-	-	-	-	-	+	+	-	-	+	
Booted Warbler	*Iduna caligata*	I			LC	WV	+	-	-	-	-	+	-	-	-	+	
Sykes's Warbler	*Iduna rama*	I			LC	WV	+	-	-	-	-	-	-	-	-	-	
Family Aegithinidae																	
Common Iora	*Aegithina tiphia*	I	Shirishot	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Family Alaudidae																	
Rufous-tailed Lark	*Ammomanes phoenicura*	O			LC	R	+	-	-	-	-	+	-	-	-	+	
Skye's Short-toed Lark	*Calandrella dukhunensis*	I					+	-	+	-	-	-	-	-	-	-	
Ashy-crowned Sparrow Lark	*Eremopterix griseus*	G			LC	R	-	-	-	-	-	-	-	-	-	+	
Crested Lark	*Galerida cristata*	O			LC	R	-	-	-	-	-	-	-	-	-	+	
Indian Bushlark	*Mirafra erythroptera*	O			LC	R	-	-	-	-	-	-	-	-	-	+	
Family Artamidae																	
Ashy Woodswallow	*Artamus fuscus*	I		IES	LC	R	-	+	-	-	+	+	-	-	-	+	
Family Campephagidae																	
Large Cuckooshrike	*Coracina macei*	I	Gaekwad	IES	LC	R	+	+	+	+	+	+	+	-	-	+	
Black-headed Cuckooshrike	*Lalage melanoptera*	I			LC	SV	-	-	+	+	-	-	-	-	+	+	
Small Minivet	*Pericrocotus cinnamomeus*	I		IES	LC	R	+	+	+	+	+	+	+	+	+	+	
White-bellied Minivet	*Pericrocotus erythropygius*	I			LC	UNK	-	-	-	-	-	-	-	+	-	-	
Rosy Minivet	*Pericrocotus roseus*	I				VAG	-	-	-	-	-	-	-	-	-	-	D
Orange Minivet	*Pericrocotus flammeus*	I		FIS	LC	R	+	+	+	+	+	+	+	-	+	+	
Family Chloropseidae																	
Golden-fronted Leafbird	*Chloropsis aurifrons*	O	Nilfesa	FIS	LC	R	+	+	+	+	+	+	+	+	+	+	
Jerdon's Leaf Bird	*Chloropsis jerdoni*	O	Nilfesa	IES	LC	R	-	+	-	-	+	+	+	-	+	+	
Family Cisticolidae																	
Zitting Cisticola	*Cisticola juncidis*	I			LC	R	-	-	-	-	-	-	-	+	-	+	
Common Tailorbird	*Orthotomus sutorius*	I	Darjido/ Liliyo/Tilliyo	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Rufous-fronted Prinia	*Prinia buchanani*	I			LC	R	-	-	-	-	-	-	-	-	-	+	
Graceful Prinia	*Prinia gracilis*	I			LC	R	+	-	-	-	-	-	-	-	-	-	
Grey-breasted Prinia	*Prinia hodgsonii*	I		IES	LC	R	-	+	+	+	+	-	-	-	+	+	
Plain Prinia	*Prinia inornata*	I			LC	R	-	-	-	-	-	+	+	+	+	+	
Ashy Prinia	*Prinia socialis*	I		FIS	LC	R	-	+	-	+	-	+	+	-	-	+	

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Jungle Prinia	*Prinia sylvatica*	I			LC	R	+	-	-	-	+	+	-	-	-	+	
Family Corvidae																	
Large-billed Crow	*Corvus macrorhynchos*	O	Kagdo	FES	LC	R	-	+	+	+	+	+	+	-	+	+	
House Crow	*Corvus splendens*	O	Kagdo		LC	R	+	+	+	+	+	+	-	-	-	+	
White-bellied Treepie	*Dendrocitta leucogastra*	O			LC	UNK	-	-	-	-	-	-	-	-	-	-	E
Rufous Treepie	*Dendrocitta vagabunda*	O	Khasa/ Karooli	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Family Dicaeidae																	
Thick-billed Flowerpecker	*Dicaeum agile*	O	Chik-Chika		LC	R	+	+	+	+	+	+	+	+	+	+	
Pale-billed Flowerpecker	*Dicaeum erythrorhynchos*	O	Chik-Chika	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Family Dicruridae																	
White-bellied Drongo	*Dicrurus caerulescens*	I	Kabri Bandoli	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Ashy Drongo	*Dicrurus leucophaeus*	I			LC	WV	+	-	+	+	+	+	+	-	+	+	
Black Drongo	*Dicrurus macrocercus*	I	Kali Bandoli	FES	LC	R	-	+	+	+	+	+	+	-	+	+	
Greater Racket-tailed Drongo	*Dicrurus paradiseus*	I	Bhingraj	IES	LC	R	+	+	+	+	+	+	+	-	+	+	
Family Emberizidae																	
Black-headed Bunting	*Emberiza melanocephala*	O			LC	WV	-	-	-	-	-	-	-	+	-	+	
Crested Bunting	*Emberiza lathami*				LC	R	-	-	-	-	-	-	-	-	-	+	
Family Estrildidae																	
Red Avadavat	*Amandava amandava*	O			LC	R	-	-	+	-	+	-	-	-	-	-	
Green Avadavat	*Amandava formosa*	O			VU	R	-	-	+	-	-	-	-	-	-	-	
Indian Silverbill	*Euodice malabarica*	O			LC	R	-	-	-	-	-	+	-	+	-	+	
Tricoloured Munia	*Lonchura malacca*	O			LC	R	-	-	-	-	+	-	-	-	-	-	
Scaly-breasted Munia	*Lonchura punctulata*	O	Jhora		LC	R	-	-	+	-	+	+	-	-	-	+	
White-rumped Munia	*Lonchura striata*	O	Jharu		LC	R	+	-	-	+	+	+	-	-	-	+	
Family Fringillidae																	
Common Rosefinch	*Carpodacus erythrinus*	G			LC	WV	+	-	-	+	+	-	-	-	-	+	
Family Hirundinidae																	
Red-rumped Swallow	*Cecropis daurica*	I			LC	R	+	+	-	+	+	+	+	+	+	+	
Barn Swallow	*Hirundo rustica*	I			LC	WV	-	-	-	-	+	+	+	-	+	+	
Wire-tailed Swallow	*Hirundo smithii*	I			LC	R	-	-	-	-	+	+	-	+	-	+	
Streak-throated Swallow	*Petrochelidon fluvicola*	I			LC	R	-	-	-	-	-	+	-	-	-	+	
Dusky Crag Martin	*Ptyonoprogne concolor*	I			LC	R	+	+	-	+	-	+	+	+	-	+	
Eurasian Crag Martin	*Ptyonoprogne rupestris*	I			LC	WV	+	-	-	+	-	+	-	-	-	-	
Plain sand Martin/ Grey-throated Martin	*Riparia chinensis*	I			LC	R	-	-	+	-	-	-	-	-	-	+	
Family Laniidae																	
Brown Shrike	*Lanius cristatus*	I			LC	WV	+	-	-	+	+	+	-	-	-	+	
Masked Shrike	*Lanius nubicus*	I			LC	VAG	-	-	-	-	-	-	-	-	-	-	F

Common name	Scientific name	Guild	Local name	Habitat preference	IUCN Status	Local status	1	2	3	4	5	6	7	8	9	10	11
Long-tailed Shrike	*Lanius schach*	I			LC	R	+	-	+	+	+	+	-	-	-	+	
Bay-backed Shrike	*Lanius vittatus*	I	Kanchya		LC	R	-	-	-	-	-	+	-	+	+	+	
Family Leiothrichidae																	
Common Babbler	*Argya caudata*	I			LC	R	-	-	-	-	+	-	+	-	+	+	
Large Grey Babbler	*Argya malcolmi*	I			LC	R	-	-	-	-	-	-	-	+	-	+	
Jungle Babbler	*Argya striata*	I	Khigdo	IES	LC	R	+	+	+	+	+	+	+	-	+	+	
Family Monarchidae																	
Black-naped Monarch	*Hypothymis azurea*	I		FIS	LC	R	+	+	+	+	+	+	+	+	+	+	
Indian Paradise-flycatcher	*Terpsiphone paradisi*	I	Dudhraj	IES	LC		+	+	+	+	+	+	+	+	+	+	
Family Motacillidae																	
Tawny Pipit	*Anthus Campestris*	I			LC	WV	-	-	-	-	-	-	-	-	-	+	
Olive-backed Pipit	*Anthus hodgsoni*	I			LC	WV	+	-	-	-	-	+	-	-	-	-	
Paddyfield Pipit	*Anthus rufulus*	I			LC	R	-	-	-	-	-	-	-	-	+	+	
Tree Pipit	*Anthus trivialis*	I			LC	WV	+	-	-	+	+	+	+	+	-	+	
Forest Wagtail	*Dendronanthus indicus*	O			LC	WV	+	-	+	-	-	-	-	-	-	+	
White Wagtail	*Motacilla alba*	AQ			LC	WV	-	+	-	+	+	+	+	+	+	+	
Grey Wagtail	*Motacilla cinerea*	AQ	Titvi	FIS	LC	WV	+	+	-	+	+	+	+	+	+	+	
Citrine Wagtail	*Motacilla citreola*	AQ			LC	WV	+	-	-	+	+	+	+	-	-	+	
Western Yellow Wagtail	*Motacilla flava*	AQ			LC	WV	-	-	+	-	+	+	+	-	+	+	
White-browed Wagtail	*Motacilla maderaspatensis*	AQ			LC	R	-	-	-	-	-	-	-	-	-	+	
Family Muscicapidae																	
Brown Rock Chat	*Oenanthe fusca*	I			LC	R	-	-	-	-	-	+	-	+	-	+	
White-rumped Shama	*Copsychus malabaricus*	I		FIS	LC	R	+	+	+	+	+	+	-	+	+	+	
Oriental Magpie Robin	*Copsychus saularis*	I	Khaprya chor	IES	LC	R	+	+	+	+	+	+	+	-	+	+	
Tickell's Blue Flycatcher	*Cyornis tickelliae*	I	Titari	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Verditer Flycatcher	*Eumyias thalassinus*	I	Titari	FIS	LC	WV	-	+	+	+	+	+	+	+	+	+	
Taiga Flycatcher	*Ficedula albicilla*	I	Titari		LC	WV	-	-	-	-	+	+	-	+	+	+	
Red-breasted Flycatcher	*Ficedula parva*	I	Titari	IES	LC	WV	+	+	+	+	+	+	+	+	+	+	
Ultramarine flycatcher	*Ficedula superciliaris*	I	Titari		LC	WV	-	+	-	-	-	+	+	+	+	+	
Bluethroat	*Luscinia svecica*	I			LC	WV	-	-	-	-	-	+	+	+	-	+	
Blue-capped Rock Thrush	*Monticola cinclorhyncha*	I			LC	WV	+	-	-	+	+	-	-	+	-	+	
Blue Rock Thrush	*Monticola solitarius*	I			LC	WV	+	-	-	+	-	-	-	+	-	+	
Asian Brown Flycatcher	*Muscicapa dauurica*	I	Titari		LC	WV	+	+	-	-	-	+	+	+	+	+	
Rusty-tailed Flycatcher	*Ficedula ruficauda*	I			LC	WV	-	-	-	-	-	-	-	+	-	-	
Malabar Whistling Thrush	*Myophonus horsfieldii*	I		FIS	LC	R	+	+	-	+	-	+	+	+	+	+	
Black Redstart	*Phoenicurus ochruros*	I		IES	LC	WV	-	+	-	+	+	-	-	+	-	+	
Pied bushchat	*Saxicola caprata*	I			LC	R	-	-	-	-	-	+	+	-	-	+	
Siberian Stonechat	*Saxicola maurus*	I			LC	WV	+	-	-	-	-	+	-	+	-	+	

Common name	Scientific name	Guild	Local name	Habitat preference	IUCN Status	Local status	1	2	3	4	5	6	7	8	9	10	11
Indian Robin	*Copsychus fulicatus*	I			LC	R	+	-	-	+	-	+	+	-	-	+	
Family Nectariniidae																	
Vigor's Sunbird	*Aethopyga vigorsii*	N	Choohi	FIS	LC	R	+	+	+	+	+	+	+	+	+	+	
Purple Sunbird	*Cinnyris asiaticus*	N	Choohi	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Purple-rumped Sunbird	*Leptocoma zeylonica*	N	Choohi		LC	R	-	-	+	+	+	+	+	+	-	+	
Family Oriolidae																	
Indian Golden Oriole	*Oriolus kundoo*	O	Haldiya		LC	R	+	+	+	+	+	+	+	+	+	+	
Black-hooded Oriole	*Oriolus xanthornus*	O	Haldiya	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Family Paridae																	
White-naped Tit	*Machlolophus nuchalis*	I			VU	R	-	-	-	-	-	-	-	-	-	+	
Indian Yellow Tit	*Machlolophus aplonotus*	I			LC	R	+	-	-	-	-	+	+	+	-	+	
Great Tit/ Cinereous Tit	*Parus cinereus*	I	Bibi Chowdhra	IES	LC	R	+	+	+	+	+	+	+	-	+	+	
Family Passeridae																	
Yellow-throated Sparrow	*Gymnoris xanthocollis*	O	Chivan Sakhar	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
House Sparrow	*Passer domesticus*	G			LC	R	+	+	+	+	+	+	+	+	-	+	
Family Pellorneidae																	
Brown-cheeked Fulvetta/ Quaker Tit Babbler	*Alcippe poioicephala*	I		FIS	LC	R	+	+	+	+	+	+	+	-	+	+	
Puff-throated Babbler	*Pellorneum ruficeps*	I		FIS	LC	R	+	+	+	+	-	+	-	-	+	+	
Family Phylloscopidae																	
Common Chiffchaff	*Phylloscopus collybita*	I			LC	WV	-	-	-	+	+	+	-	-	-	+	
Sulphur-bellied Warbler	*Phylloscopus griseolus*	I		IES	LC	WV	+	-	-	+	+	+	+	+	-	+	
Hume's Leaf Warbler	*Phylloscopus humei*	I		IES	LC	WV	+	-	-	-	-	+	-	-	-	+	
Yellow-browed Warbler	*phylloscopus inornatus*	I		IES	LC	WV	-	+	-	+	-	-	-	-	-	-	
Green Warbler	*Phylloscopus nitidus*	I		IES	LC	PV	+	-	-	-	-	+	+	+	-	+	
Western Crowned Warbler	*Phylloscopus occipitalis*	I		IES	LC	WV	+	-	-	+	-	-	-	-	-	-	
Greenish Warbler	*Phylloscopus trochiloides*	I		IES	LC	WV	+	+	-	+	+	+	+	-	-	+	
Tytler's leaf Warbler	*Phylloscopus tytleri*	I		IES	LC	WV	+	-	-	-	-	-	-	-	-	-	
Family Pittidae																	
Indian Pitta	*Pitta brachyura*	I	Gofli		LC	SV	-	+	+	+	+	-	-	+	+	+	
Family Ploceidae																	
Baya Weaver	*Ploceus Philippinus*	G	Sugri		LC	R	-	-	-	-	-	-	-	-	-	+	
Family Pycnonotidae																	
Red-vented Bulbul	*Pycnonotus cafer*	O	Bulbuliyo/ Pistolia/ phesra	FES	LC	R	+	+	+	+	+	+	+	+	+	+	
Red-Whiskered Bulbul	*Pycnonotus jocosus*	O			LC	R	+	-	-	-	-	+	+	+	+	+	
White-eared Bulbul	*Pycnonotus leucotis*	O			LC	R	-	-	-	-	+	+	+	+	-	+	
White-Browed Bulbul	*Pycnonotus luteolus*	O		IES	LC	R	-	+	-	-	-	-	-	-	-	+	

Common name	Scientific name	Guild	Local name	Habitat preference	IUCN Status	Local status	1	2	3	4	5	6	7	8	9	10	11
Family Rhipiduridae																	
White-spotted Fantail	*Rhipidura albogularis*	I		IES	LC	R	+	-	+	-	-	-	-	-	-	+	
White-browed Fantail	*Rhipidura aureola*	I		IES	LC	R	-	-	+	+	+	+	-	-	-	+	
White-throated fantail	*Rhipidura albicollis*						-	-	+	-	-	-	-	-	-	-	
Family Sittidae																	
Velvet-fronted Nuthatch	*Sitta frontalis*	I			LC	R	+	+	-	+	-	+	+	-	-	+	
Family Stenostiridae																	
Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*	I	Titari	FIS	LC	WV	-	+	+	+	+	+	+	-	+	+	
Family Sturnidae																	
Bank Myna	*Acridotheres ginginianus*	O	Kabar	FES	LC	R	-	-	-	-	+	-	-	-	-	+	
Common Myna	*Acridotheres tristis*	O	Kabar	FES	LC	R	+	+	+	+	+	+	-	-	-	+	
Asian Pied Starling	*Gracupica contra*	O			LC	R	-	-	+	-	-	-	-	-	-	-	
Rosy Starling	*Pastor roseus*	O			LC	WV	-	-	+	-	-	+	-	+	-	+	
Chestnut-tailed Starling	*Sturnia malabarica*	O			LC	WV	-	-	-	-	-	-	-	-	-	+	
Brahminy Starling	*Sturnia pagodarum*	O		FES	LC	R	-	+	+	-	-	+	-	+	-	+	
Family Sylviidae																	
Yellow-eyed Babbler	*Chrysomma sinense*	I			LC	R	-	+	-	-	-	-	-	+	-	+	
Hume's Whitethroat	*Sylvia althaea*	I			LC	WV	+	-	-	-	-	-	-	-	-	-	
Lesser Whitethroat	*Sylvia curruca*	I			LC	WV	+	-	-	-	-	-	-	-	-	+	
Family Timaliidae																	
Tawny-bellied Babbler	*Dumetia hyperythra*	I			LC	R	+	-	+	+	+	+	-	+	+	+	
Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	I		FIS	LC	R	+	+	+	+	-	+	+	-	+	+	
Family Turdidae																	
Indian Blackbird	*Turdus simillimus*	O			LC	SV	+	-	-	-	-	+	+	-	-	+	
Tickell's Thrush	*Turdus unicolor*	O			LC	WV	-	-	-	-	-	-	-	-	-	+	
Orange-headed Thrush	*Geokichla citrina*	O		FIS	LC	R	-	+	+	+	+	+	+	-	-	+	
Family Vangidae																	
Bar-winged Flycatcher Shrike	*Hemipus picatus*	I		FIS	LC	R	+	+	-	+	-	+	+	+	-	+	
Common Woodshrike	*Tephrodornis pondicerianus*	I	Valbafiya	FIS	LC	R	+	+	+	+	+	+	+	-	+	+	
Malabar Woodshrike	*Tephrodornis sylvicola*	I	Valbafiya		LC	R	+	-	-	-	-	-	-	-	-	-	
Large Woodshirke	*Tephrodornis virgatus*	I	Valbafiya		LC	R	-	+	-	-	-	-	-	-	-	-	
Family Zosteropidae																	
Oriental White-eye	*Zosterops palpebrosus*	I	Gharya	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Order Pelecaniformes																	
Family Ardeidae																	
Grey Heron	*Ardea cinerea*	AQ	Kabro baglo		LC	R	-	-	-	-	-	-	-	+	-	+	
Indian Pond Heron	*Ardeola grayii*	AQ	Dhokla	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Cattle Egret	*Bubulcus ibis*	AQ	Bag		LC	R	+	+	+	+	+	+	+	+	+	+	

Common name	Scientific name	Guild	Local name	Habitat preference	IUCN Status	Local status	1	2	3	4	5	6	7	8	9	10	11
Striated Heron	*Butorides striata*	AQ			LC	R	+	-	-	+	-	-	+	-	-	+	
Great Egret	*Ardea alba*	AQ			LC	R	+	+	+	-	-	+	-	+	-	+	
Little Egret	*Egretta garzetta*	AQ	Bag	FES	LC	R	+	+	+	+	-	+	+	-	+	+	
Western Reef Egret	*Egretta gularis*	AQ			LC	UNK	-	-	-	-	-	+	-	-	-	+	
Intermediate Egret	*Ardea intermedia*	AQ			LC	R	+	-	-	+	+	+	+	+	-	+	
Family Threskiornithidae																	
Glossy Ibis	*Plegadis falcinellus*	O	Kokanghar		LC	WV	-	-	-	-	-	-	-	-	+	+	
Red-naped Ibis	*Pseudibis papillosa*	O	Kokanghar		LC	R	+	+	+	+	+	+	+	-	+	+	
Black-headed Ibis	*Threskiornis melanocephalus*	O	Kokanghar		NT	WV	-	-	-	-	+	-	-	-	-	+	
Order Piciformes																	
Family Megalaimidae																	
Coppersmith Barbet	*Psilopogon haemacephalus*	F	Popli	FES	LC	R	+	+	+	+	+	+	+	+	+	+	
White-cheeked Barbet	*Psilopogon viridis*	F	Kukroos	FIS	LC	R	+	+	-	+	-	+	+	-	-	+	
Brown-headed Barbet	*Psilopogon zeylanicus*	F		IES	LC	R	+	+	+	+	+	+	+	-	+	+	
Family Picidae																	
White-naped Woodpecker	*Chrysocolaptes festivus*	I	Tirga		LC	R	+	-	-	+	-	+	+	-	+	+	
Greater Flameback	*Chrysocolaptes guttacristatus*	I	Tirga		LC	R	+	-	+	+	+	+	-	+	+	+	
Yellow- -fronted Woodpecker	*Leiopicus mahrattensis*	I	Tirga	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Brown-capped pygmy Woodpecker	*Yungipicus nanus*	I	Bobdi Tirga	FIS	LC	R	+	+	+	+	+	+	+	+	+	+	
Black-rumped Flameback /Lesser Goldenback	*Dinopium benghalense*	I	Tirga	IES	LC	R	+	+	+	+	+	+	+	-	+	+	
White-bellied Woodpecker	*Dryocopus javensis*	I	Hardiya Tirga	FIS	LC	R	+	+	+	+	+	+	-	+	-	+	
Heart-spotted Woodpecker	*Hemicircus canente*	I	Tirga	FIS	LC	R	+	+	-	+	+	+	+	-	-	+	
Eurasian Wryneck	*Jynx torquilla*	I			LC	WV	-	-	-	-	-	-	-	+	-	+	
Rufous Woodpecker	*Micropternus brachyurus*	I	Tirga		LC	R	+	+	-	+	-	+	+	+	-	+	
Lesser Yellownape	*Picus chlorolophus*	I	Tirga	FIS	LC	R	+	+	-	+	-	-	-	-	-	+	
Streak-throated Woodpecker	*Picus xanthopygaeus*	I	Tirga		LC	R	-	-	-	-	+	-	-	-	-	-	
Order Podicipediformes																	
Family Podicipedidae																	
Little Grebe	*Tachybaptus ruficollis*	AQ			LC	R	-	+	-	+	+	+	+	-	-	+	
Order Psittaciformes																	
Family Psittaculidae																	
Plum-headed Parakeet	*Psittacula cyanocephala*	F	Tuhi/Popat	IES	LC	R	+	+	+	+	+	+	+	+	+	+	
Alexandrine Parakeet	*Psittacula eupatria*	F	Popat/ Hudo	IES	NT	R	+	+	+	+	+	+	+	+	+	+	
Rose-ringed Parakeet	*Psittacula krameri*	F	Popat	FES	LC	R	+	+	+	+	+	+	+	+	+	+	
Order Strigiformes																	
Family Strigidae																	

Common name	Scientific name	Guild	Local name	Habitat preference	IUCN Status	Local status	1	2	3	4	5	6	7	8	9	10	11
Short-eared Owl	*Asio Flammeus*	C	Duda		LC	WV	+	-	-	-	-	-	-	-	-	-	
Spotted Owlet	*Athene brama*	C	Chirbiliya Duda/ Chibri		LC	R	+	-	+	+	+	+	-	+	-	+	
Indian Eagle Owl	*Bubo bengalensis*	C	Motha Duda		LC	R	+	+	-	-	-	+	-	-	-	+	
Dusky Eagle Owl	*Bubo coromandus*	C			LC	R	-	-	+	-	-	-	-	-	-	-	
Jungle Owlet	*Glaucidium radiatum*	C	Kabra / Jungli Duda	FIS	LC	R	+	+	+	+	+	+	+	+	+	+	
Forest Owlet	*Athene blewitti*	C	Barik Thorpia Duda		EN	R	-	-	+	-	-	+	-	+	-	+	
Brown Fish Owl	*Ketupa zeylonensis*	C	Machimaar Dudo		LC	R	-	-	-	+	-	+	+	-	-	+	
Brown Hawk Owl	*Ninox scutulata*	C			LC	R	+	+	-	+	-	+	-	+	-	+	
Indian Scops Owl	*Otus bakkamoena*	C			LC	R	+	-	-	+	+	+	-	-	-	+	
Eurasian Scops Owl	*Otus scops*	C			LC	WV	-	-	+	-	-	-	-	-	-	-	
Oriental Scops Owl	*Otus sunia*	C			LC	R	-	-	-	-	-	+	-	-	-	+	
Brown Wood Owl	*Strix leptogrammica*	C			LC	R	-	-	-	+	+	+	-	-	-	+	
Mottled Wood Owl	*Strix ocellata*	C			LC	R	+	+	-	-	+	+	-	-	-	+	
Family Tytonidae																	
Common Barn Owl	*Tyto alba*	C	Chihar		LC	R	-	+	+	+	+	-	-	-	-	+	
Order Suliformes																	
Family Phalacrocoracidae																	
Indian Cormorant	*Phalacrocorax fuscicollis*	AQ			LC	WV	-	-	-	-	-	+	-	-	-	+	
Little Cormorant	*Microcarbo niger*	AQ	Kar		LC	WV	-	+	+	+	+	+	+	-	+	+	
Order Trogoniformes																	
Family Trogonidae																	
Malabar Trogon	*Harpactes fasciatus*	I	Bhishkhigar	FIS	LC	R	+	+	+	+	+	+	+	-	+	+	

compartment 7 of PWS, while resting at Waghdarda checkpost, a call of Nightjar was heard by NJ around 20.15h. The call was typical 'Chaunk Chaunk Chaunk….'. Immediately the call was tallied with the pre-recorded call and confirmed as a call of Large-tailed Nightjar. The sighting of Trivedi & Soni (2006) in Ratanmahal WS was the first record for the state; however, the species was not recorded by Trivedi & Soni (2006) from PWS. This record substantiated the range extension of Large-tailed Nightjar further south by approximately 90km. It is also a new record for PWS. Also, eight individuals of this species have been sighted by Mishra & Singh (2010) from the Phot Mahadev thorn forest in Kutch District. Ganpule (2016) mentioned this species as a rare winter visitor.

Streak-throated Woodpecker *Picus xanthopygaeus* (J.E. & G.R. Gray, 1847)

On 6 April 2013, while walking a trail in compartment 56 of the Bardipada range, a green woodpecker foraging in bamboo thickets was observed by NJ. Knowing that it is not among the commonly found woodpeckers, photographs of the bird were taken immediately and identified as Streak-throated Woodpecker. This species was recorded from Shoolpaneshwar Wildlife Sanctuary, which delimits its southernmost range (Desai et al. 1993). Our record extends its range approximately by 40km towards the south, and it is also a new record for PWS. According to Ganpule (2016), the species is uncommon to a rare resident in the north to south forests of Gujarat but is not recorded elsewhere in the state.

Rusty-tailed Flycatcher *Ficedula ruficauda* Swainson, 1838

One individual of *Ficedula ruficauda* was photographed by Shailesh Gupta on 4 February 2017 during DBF 2017. This sighting is the first record from Dangs. Besides

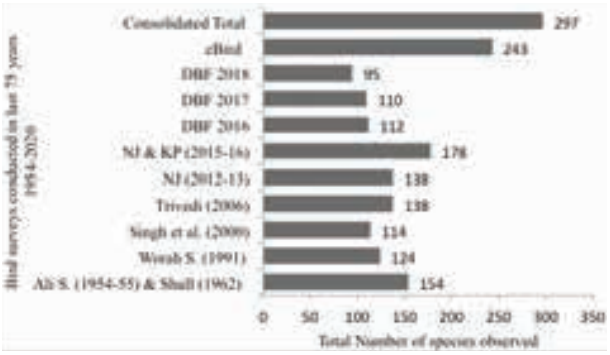

Figure 1. Number of species documented during different studies in Surat-Dangs landscape.

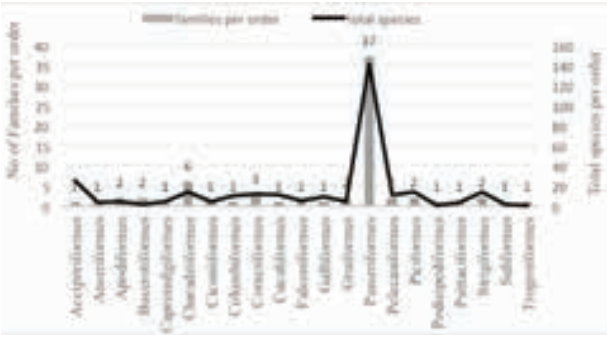

Figure 2. Family and order representation of Avifauna from the Surat-Dangs landscape.

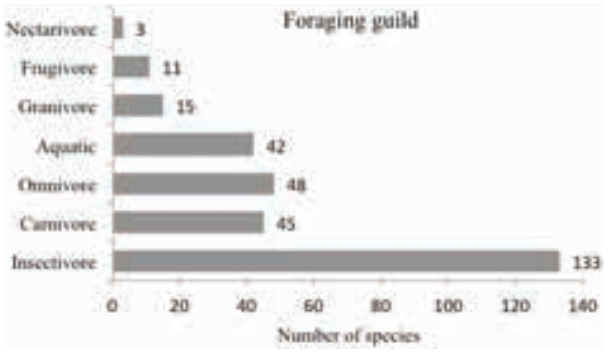

Figure 3. Composition of birds belonging to various foraging guilds in Surat-Dangs landscape.

this, one sighting from Morbi (Ganpule 2014b) and few from Girnar Mountains had been reported from Gujarat (Bagda 2017, 2019; Ghervada 2019; Vachhani 2019).

Lesser Whistling Duck *Dendrocygna javanica* (Horsfield, 1821)

On 15 June 2012, NJ observed 10 individuals of Lesser Whistling Duck swimming in the Purna River near Mahal campsite, which is the first record from Dangs. Ali (1954–55) had noted this species as resident fairly common locally, but not abundant in Gujarat. Worah (1991) and Trivedi (2003) also did not report the species from Dangs. Recently this species has been recorded from areas surrounding Dangs, viz., Doswada (Songadh), Maya Lake (near Raghipura), Rangavali Dam (Nandurbar, Maharashtra), Vyara and Vansda NP (Chaudhari 2014; Tembhekar 2015; Patel 2015; Patel 2016; Jamadar 2019).

Rosy Minivet *Pericrocotus roseus* (Vieillot, 1818)

Rosy Minivet is mainly found (breeding) in the Himalaya from west to east up to Arunachal Pradesh and hills of Manipur, and winter-visitor to peninsular India (Birdlife International 2018b). Globally, the species is found in Afghanistan, Bangladesh, Bhutan, China, Nepal, Pakistan, Thailand, and Vietnam. The species was not listed in the Gujarat bird checklist (Ganpule 2016, 2017). First photographic evidence of this species was confirmed by Patel (2017a) from VNP. Another record was from VNP (Prakash 2017) and a closest photographic evidence was found on eBird platform from Tansa Wildlife Sanctuary (in Maharashtra State) in 2016 (Kasare 2016).

White-bellied Minivet *Pericrocotus erythropygius* (Jerdon, 1840)

Two individuals were sighted by one of the participants of DBF 2017 from the Bheskatri Trail team led by NJ. Ganpule (2016) mentions the species as uncommon to a rare resident. The species has been reported from the thorn and scrub forests of Kutch, Gir National Park and Hingolgadh in Saurashtra (Ganpule 2016). There has been no other record of the species from Dangs landscape till date and further investigation on the distribution of species in the landscape is necessary.

Threatened species to local extinction

Long-billed Vulture *Gyps indicus* (Scopoli, 1786)

In March 2016, 43 individuals of Long-billed Vulture were observed during the 'Dangs Vulture Census' with nesting and egg hatchling activity at Gadad Village, Piplai Devi range, Dangs. The state level vulture census was also conducted by the GEER foundation on 28 and 29 May 2016 from Dangs District (Kamboj et al. 2016). Since 2007, the Long-billed Vulture is the only vulture species reported from the Dangs. Its population is becoming stable now: eight individuals in 2005, 43 in 2007, 58 in 2010, 67 in 2012, and 43 in 2016 (Kamboj et al. 2016). Within the Gujarat State, the *Gyps* Vulture population has undergone a drastic decline to complete extirpation from many localities, including the nearest population from the Surat District (Kamboj et al. 2016). The nesting

population of 43 Long-billed Vulture in Dangs needs immediate conservation attention to prevent its local extinction from the district. The same locality (Gadad) has seen local extinction of *Gyps bengalensis* (White-rumped Vulture) recently. Although, one sighting of *Gyps bengalensis* has been recorded from Dangs in flight (Patel 2016; Andharia 2019), possibly a passer-by from the neighboring population in Valsad (Gujarat) and Nashik (Maharashtra) districts (Kamboj et al. 2016).

Indian Peafowl *Pavo cristatus* Linnaeus, 1758

The species is common and highly abundant in many protected areas and metro city parks or human-dominated areas. The species is also part of the diet of large carnivores like Tiger, Leopard, and Dhole (Arviazhagan et al. 2007). In Dangs, the species is heavily poached for its meat due to its large body size and tasteful flesh. There are very few records of the species from Dangs. It is a rare resident in the landscape.

Red Junglefowl *Gallus gallus* (Linnaeus, 1758)

Ali (1954–55) had not mentioned about Red Junglefowl *Gallus gallus* during his field-trips to Gujarat State. Ali (1954–55) had collected *G. spadicea* and *G. Sonneratii* (but not *G. gallus*) from Dangs; however, Ganpule (2016) mentioned that the species could be vagrant or rare resident with probable occurrence ("?") in the forest belt of southern Gujarat. The species was once spotted on 6 February 2016 on Girmal track by one of the DBF 2016 team. Two individuals were also recorded from Girmal, carrying nesting material on 26 July 2017 (Theba 2017a).

Grey Junglefowl *Gallus sonneratii* Temminck, 1813

Grey Junglefowl *Gallus sonneratii* was observed in 2012–13 from the Mahal waterfall trail, in 2016 from Girmal, Bardipada, conservation plot, Koshmal, and Bheskatri. During DBF 2018, on 10 and 11 February 2018, it was observed by two different teams in Mahal track. The species can be easily heard in the early mornings near the Mahal campsite and relatively common among two other members (*G. spadicea* and *G. gallus*); however, the species is also susceptible to habitat change as well as hunting.

White-bellied Woodpecker *Dryocopus javensis* (Horsfield, 1821)

Surat-Dangs is the northernmost site for the White-bellied Woodpecker in India and the westernmost limit of its global range (Grimmett et al. 2014). The species is found only in Surat-Dangs forests of Gujarat State (Ganpule 2016). It is the largest woodpecker of peninsular India and is a bird of primary moist deciduous forest and secondary forest. It is also seen in tropical evergreen and semi-evergreen forest, while it nests in large dead trees (Ali & Ripley 1983; Grimmett et al. 1998). In Gujarat, primary moist deciduous forest is the preferred habitat of species. The conversion of primary moist deciduous forests to either secondary forests or plantations has resulted in reduced availability of suitable nesting trees (Worah 1991; Santharam 2003). The population of this species is patchy and not connected. Ali (1954–1955) reported that tribal people hunt the species in Dangs District. The species is highly susceptible to local extinction due to hunting and less availability of nesting trees. It is comparatively easy to find the species in Conservation plot in PWS and VNP, but is rare in other parts of the landscape. Evaluation of its distribution and immediate conservation action is needed to prevent the local extinction of the species in the landscape.

Endemic bird species

Forest Owlet *Athene blewitti* Hume, 1873

Existence of this rare and endemic species has been doubtful in Dangs District of Gujarat State for many years (Khacher 1996). The first unconfirmed record was noted during the biodiversity survey of VNP on 30.12.1998 from Kevdi locality (Singh et al. 2000). The first confirmed record with photographic evidence was reported from PWS in 2015 (Patel et al. 2015). The survey by KP (2015–2016) has revealed that the species is not restricted to PAs, but widely distributed throughout the Dangs District (Figure 4) and is fairly common in the agricultural fields, along with the teak dominated forest patches. The Dangs forest holds the second largest population with a total of at least 51 individuals, next only to Melghat, Maharashtra. Also, the population size could be much higher than what has been observed in the landscape; however, the positive locations outside the protected area are highly vulnerable to forest fire, habitat destruction, poaching and hunting, use of its body parts in religious rituals as well as illegal wildlife trade. The species is listed under the Endangered category of IUCN (Birdlife International 2018a). Dangs forests possess one of the highly suitable sites for the species and negligible use of rodenticide in the landscape (Worah 1991; Trivedi & Soni 2006) could provide sufficient prey species to the diet of Forest Owlet. The Dangs forests are one of the strongholds for the species and can support its long-term conservation.

Grey-fronted Green Pigeon *Treron affinis* (Jerdon, 1840)

Grey-fronted Green Pigeon is a bird species endemic

Table 2. Species list as per Important Bird Area criteria by Birdlife International.

	Family	English name	Scientific name	IUCN Red List
IBA Criteria A1. Globally threatened species				
1	Accipitridae	White-rumped Vulture	*Gyps bengalensis*	CR
2	Accipitridae	Indian Vulture	*Gyps indicus*	CR
3	Accipitridae	Egyptian Vulture	*Neophron percnopterus*	EN
4	Strigidae	Forest Owlet	*Athene blewitti*	EN
5	Accipitridae	Greater Spotted Eagle	*Clanga clanga*	VU
6	Accipitridae	Tawny Eagle	*Aquila rapax*	VU
7	Ciconiidae	Wolly-necked Stork	*Ciconia episcopus*	VU
8	Columbidae	Nilgiri Wood Pigeon	*Columba elphinstonii*	VU
9	Estrildidae	Green Avadavat	*Amandava formosa*	VU
10	Paridae	White-naped Tit	*Machlolophus nuchalis*	VU
11	Gruidae	Sarus Crane	*Antigone antigone*	VU
12	Acrocephalidae	Large-billed Reed Warbler	*Acrocephalus orinus*	DD
13	Accipitridae	Pallid Harrier	*Circus macrourus*	NT
14	Accipitridae	Grey-Headed Fish Eagle	*Haliaeetus ichthyaetus*	NT
15	Burhinidae	Great Thick-knee	*Esacus recurvirostris*	NT
16	Ciconiidae	Painted Stork	*Mycteria leucocephala*	NT
17	Laridae	River Tern	*Sterna aurantia*	NT
18	Psittaculidae	Alexandrine Parakeet	*Psittacula eupatria*	NT
19	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*	NT
IBA Criteria A2. Restricted range species				
1	Columbidae	Nilgiri Wood Pigeon	*Columba elphinstonii*	VU
2	Columbidae	Grey-fronted Green Pigeon	*Treron (pompadora) affinis*	LC
3	Vangidae	Malabar Woodshrike	*Tephrodornis (virgatus) sylvicola*	LC
4	Nectariniidae	Vigor's Sunbird	*Aethopyga (siparaja) vigorsii*	LC
5	Strigidae	Forest Owlet	*Athene blewitti*	EN
IBA Criteria A3. Biome restricted species				
	AS07 Sino-Himalayan temperate forest		**1 out of 183= 0.55%**	
1	Muscicapidae	Ultramarine flycatcher	*Ficedula superciliaris*	LC
	AS08	**Sino-Himalayan sub-tropical forest**	**1 out of 169= 0.59%**	
2	Sturnidae	Rosy Starling	*Pastor roseus*	LC
	AS10 Indian peninsula tropical moist forest		**8 out of 55= 14.54%**	
3	Columbidae	Nilgiri Wood Pigeon	*Columba elphinstonii*	VU
4	Cuculidae	Blue-faced Malkoha	*Phaenicophaeus viridirostris*	LC
5	Strigidae	Forest Owlet	*Athene blewitti*	EN
6	Trogonidae	Malabar Trogon	*Harpactes fasciatus*	LC
7	Megalaimidae	White-cheeked Barbet	*Psilopogon viridis*	LC
8	Muscicapidae	Malabar Whistling Thrush	*Myophonus horsfieldii*	LC
9	Timaliidae	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*	LC
10	Corvidae	White Bellied Treepie	*Dendrocitta leucogastra*	LC
	AS11 Indio-Malayan tropical dry zone		**37 out of 78= 47.44%**	
11	Accipitridae	White-rumped Vulture	*Gyps bengalensis*	CR
12	Accipitridae	Indian Vulture	*Gyps indicus*	CR

	Family	English name	Scientific name	IUCN Red List
13	Accipitridae	White-eyed Buzzard	*Butastur teesa*	LC
14	Phasianidae	Painted Francolin	*Francolinus pictus*	LC
15	Phasianidae	Jungle Bush Quail	*Perdicula asiatica*	LC
16	Phasianidae	Indian Peafowl	*Pavo cristatus*	LC
17	Columbidae	Grey-fronted Green Pigeon	*Treron (pompadora) affinis*	LC
18	Psittaculidae	Plum-headed Parakeet	*Psittacula cyanocephala*	LC
19	Cuculidae	Sirkeer Malkoha	*Taccocua leschenaultii*	LC
20	Strigidae	Dusky Eagle Owl	*Bubo coromandus*	LC
21	Muscicapidae	Indian Robin	*Saxicoloides fulicatus*	LC
22	Pycnonotidae	White-Browed Bulbul	*Pycnonotus luteolus*	LC
23	Vangidae	Common Woodshrike	*Tephrodornis pondicerianus*	LC
24	Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	LC
25	Campephagidae	White-bellied Minivet	*Pericrocotus erythropygius*	LC
26	Alaudidae	Ashy-crowned Sparrow Lark	*Eremopterix griseus*	LC
27	Alaudidae	Indian Bushlark	*Mirafa erythroptera*	LC
28	Picidae	White-naped Woodpecker	*Chrysocolaptes festivus*	LC
29	Picidae	Lesser Goldenback	*Dinopium benghalense*	LC
30	Picidae	Yellow-fronted Woodpecker	*Dendrocopos mahrattensis*	LC
31	Megalaimidae	White-cheeked Barbet	*Psilopogon viridis*	LC
32	Bucerotidae	Indian Grey Hornbill	*Ocyceros birostris*	LC
33	Caprimulgidae	Indian Nightjar	*Caprimulgus asiaticus*	LC
34	Strigidae	Mottled Wood Owl	*Strix ocellata*	LC
35	Muscicapidae	Brown Rock Chat	*Cercomela fusca*	LC
36	Timaliidae	Tawny-bellied Babbler	*Dumetia hyperythra*	LC
37	Leiothrichidae	Large Grey Babbler	*Turdoides malcolmi*	LC
38	Leiothrichidae	Jungle Babbler	*Turdoides striata*	LC
39	Cisticolidae	Rufous-fronted Prinia	*Prinia buchanani*	LC
40	Cisticolidae	Ashy Prinia	*Prinia socialis*	LC
41	Cisticolidae	Jungle Prinia	*Prinia sylvatica*	LC
42	Rhipiduridae	White-browed Fantail	*Rhipidura aureola*	LC
43	Paridae	White-naped Tit	*Machlolophus nuchalis*	VU
44	Estrildidae	Green Avadavat	*Amandava formosa*	VU
45	Sturnidae	Brahminy Starling	*Sturnia pagodarum*	LC
46	Sturnidae	Bank Myna	*Acridotheres ginginianus*	LC
47	Artamidae	Ashy Woodswallow	*Artamus fuscus*	LC
	AS13 Saharo-Sindian desert		**2 out of 20 = 10%**	
48	Caprimulgidae	Syke's Nightjar	*caprimulgus mahrattensis*	LC
49	Pycnonotidae	White-eared Bulbul	*Pycnonotus leucotis*	LC

to WG and southern EG (Grimmett et al. 2014). It was recorded for the first time from VNP (Singh et al. 2000) and also mentioned earlier by Parasharya et al. (2004). Ganpule (2016) mentioned that it is a rare resident from Dangs forests.

Vigor's Sunbird *Aethopyga vigorsii* (Sykes, 1832)

Rasmussen & Anderton (2005) have upgraded the WG subspecies to species rank *Aethopyga vigorsii* based on morphological differences. Vigor's sunbird is endemic to WG from south of Narmada up to Goa and in western

Satpura, Khandesh (Grimmett et al. 2014). The species is fairly common in moist deciduous and woodlands of Dangs forests.

Malabar Trogon *Harpactes fasciatus* (Pennant, 1769)

Malabar Trogon is endemic to Indian sub-continent-WG, EG, and Sri Lanka (Grimmett et al. 2014). Ali (1954–55) had collected 11 specimens of Malabar trogon from five different localities of the Dangs forests and considered it common. Today, it is uncommon resident found in moist deciduous forest with bamboo and secondary growth in protected areas of PWS and VNP (Singh et al. 2000; Trivedi & Soni 2006), where human disturbance is minimal. The species has been found sensitive to forest fragmentation (Trivedi & Soni 2006) in the Dangs forests as is the case in southern WG (Raman 2001). The species is common in conservation plot, Mahal trail and Dhuldha in PWS and undisturbed forests in VNP; however, the species is uncommon or infrequent in other parts of the landscape.

Malabar Whistling-thrush *Myophonus horsfieldii* Vigors, 1831

Malabar Whistling-Thrush is resident to WG and associated hills of peninsular India (central India and parts of EG) (Grimmett et al. 2014). This species is post-monsoon and winter visitor in the Dangs forests, mainly near stream banks and moist deciduous forests. Ali (1954–55) recorded it as a resident in Surat-Dangs forests, but it becomes rare in summer season. It is known for its melodious songs and the species is an indicator for change in hydrology (Trivedi & Soni 2006). The species is relatively common throughout the Dangs forests, but easy to find in undisturbed areas in PAs.

White-cheeked Barbet *Psilopogon viridis* (Boddaert, 1783)

White-cheeked Barbet is endemic to and found across WG and associated ranges, southern EG, while Surat-Dangs being the northernmost extent for the species (Grimmett et al. 2014). The species is restricted to moist deciduous forests and is not common. The species is accompanied by common and highly vocal species Brown-headed Barbet *M. zeylanica*, locally known as "Kukroos" owing to its call. Surat-Dangs is the only place to find this species in the Gujarat State (Trivedi & Soni 2006; Ganpule 2016).

Malabar Woodshrike *Tephrodornis sylvicola* Jerdon, 1839

Malabar Woodshrike is endemic to WGs and found in Surat-Dangs and south-west of WG from south Goa mostly at lower elevations (Birdlife International 2017c). There is a lot of discrepancy in the historical records of this species. Ali (1954–55) had collected a specimen from Waghai, Dangs; and described about its range extension from Gujarat State (page 377), where he had mentioned its name as Large Woodshrike *Tephrodornis gularis*, while on page 738, the species was mentioned as The Large Malabar Wood Shrike *Tephrodornis virgatus sylvicola* Jerdon. He had collected one male individual in breeding plumage, evidently in mating phase. The collected specimen and vocalization pattern positively matched with specimens collected from Travancore and were of *sylvicola* race (full species rank now). Worah (1991) had mentioned both Common Woodshrike and Large Woodshrike in her list, but used *Tephrodornis virgatus* for both the species. Trivedi & Soni (2006) had mentioned Large Woodshrike (*Tephrodornis) gularis* but did not report the species from PWS and suggested the species to be locally extinct from the area. It is interesting to note here that *sylvicola* was designated as a separate species by Rasmussen & Anderton (2005). Ganpule (2016) mentioned that the species is a rare vagrant in Gujarat. We believe that the species is still found in the landscape and is probably overlooked and dismissed as the more common *Tephrodornis pondicerianus.*

Indian Scimitar Babbler *Pomatorhinus horsfieldii* Sykes, 1832

Indian Scimitar Babbler is fairly common in the forests of Surat-Dangs, often foraging in parties of two to seven, hunting with mixed-species flock in the bamboo and mixed deciduous forests. The species is endemic to peninsular India (Grimmett et al. 2014). Undisturbed dense mixed deciduous forests in PAs are the best place to find the species.

White-naped Tit *Machlolophus nuchalis* (Jerdon, 1845)

White-naped tit is found in two (disjunct) populations: northwest peninsula (west and north Gujarat and southeastern Rajasthan) and southern peninsula (northwestern Karnataka to northwestern Tamil Nadu) (Jathar & Rehmani 2006). It is globally 'Vulnerable', due to natural scarcity and habitat degradation and can be used as an indicator of human disturbance and clearing forests (Birdlife International 2017b). The species is recorded from Girmal locality in PWS by Patel (2017b).

Other noteworthy bird records

Here, we give details of the species referred as forest-interior species and most of which show a documented

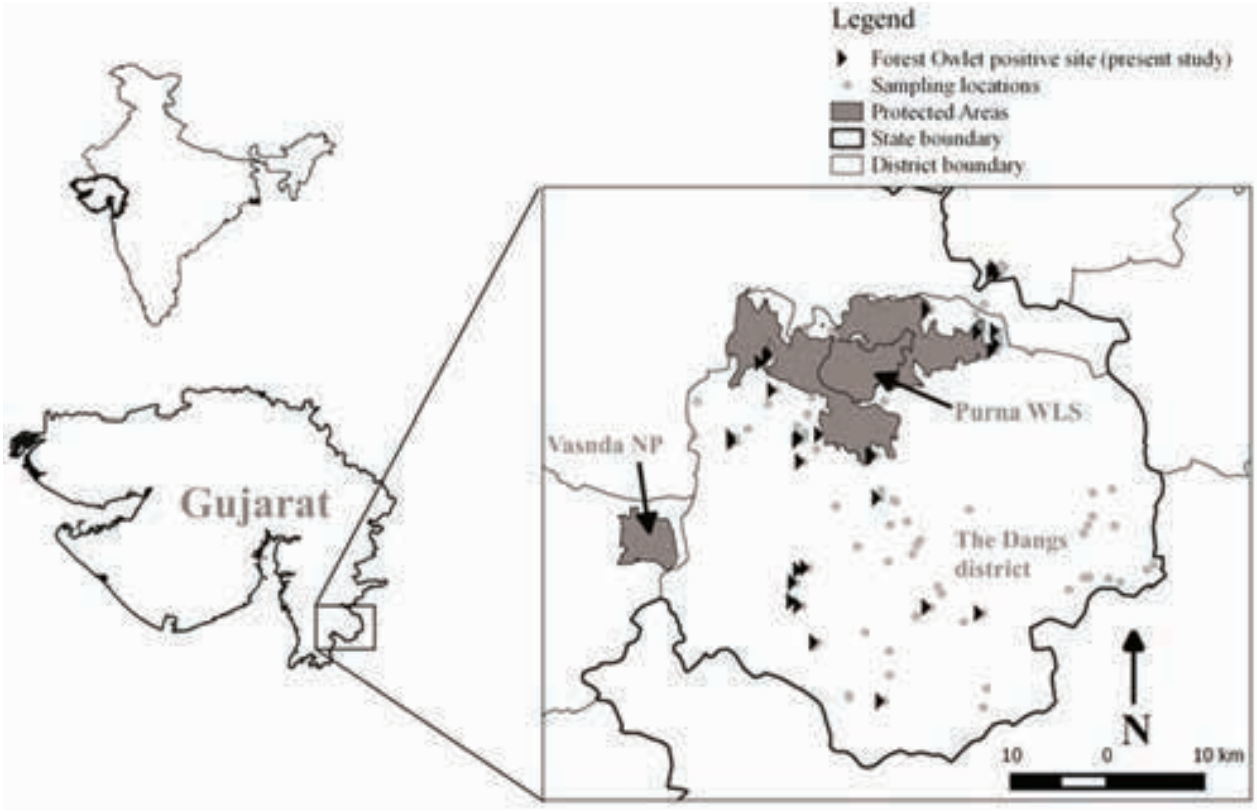

Figure 4. Forest Owlet positive sites in Dangs District.

vulnerability to forest fragmentation, alteration (Worah 1991; Trivedi & Soni 2006).

Brown Wood Owl *Strix leptogrammica* Temminck, 1832

Brown Wood Owl is widely distributed in the Himalaya, northeastern India, WG and EG (Grimmett et al. 1998); however, the species is noteworthy because it is only found in the forests of southern Gujarat State (Ganpule 2016). The species is fairly common, but tends to be missed due to its nocturnal and skulking nature. We (NJ 2012–2013, NJ and KP 2015–16) have confirmed the presence of the species from Roopgard Fort, Bardipada, Bheskatri, Kalibel, Ahwa, Malegaon and localities across the Dangs landscape by using call play-back method. There have been a few organic sightings (NJ 2012–2013) of this species too.

Black Eagle *Ictinaetus malaiensis* (Temminck, 1822)

There have been very few sightings of Black Eagle from Dangs. In 1995, two individuals were reported from VNP (Santharam 1995). In 2001, the species was spotted twice from PWS (Trivedi 2006). NJ photographed one individual from a forest near Mahal village on 19 December 2012 (Jambu 2013). No other sighting has been reported from the district. It is a rare resident of the district and more data is needed to understand its population trend.

Greater Racket-tailed Drongo *Dicrurus paradiseus* (Linnaeus, 1766)

Greater Racket-tailed Drongo is a widely distributed species (Grimmett et al. 2014); however, it is noteworthy because it is fairly common in the Dangs forests and plays a very critical role in mixed-species flocks (Trivedi & Soni 2006). The species is very active and mimic various bird calls to join hunting parties. The species plays a key role in maintaining avian diversity and controlling insect populations by forming mixed-species flocks.

Rufous Woodpecker *Micropternus brachyurus* (Vieillot, 1818)

Rufous Woodpecker is known for its peculiar habit of nesting in the nests of *Crematogaster* ants (Ali 1969). It was reported previously from Dangs (Ali 1954–1955; Worah 1991; Trivedi 2003; Bhatt 2004) but not elsewhere from Gujarat. The species can be found in bamboos with mixed deciduous forests and sometimes in a mixed-species flock. This is another species, which is likely to

go locally extinct as it is sensitive to habitat degradation. Its distribution is very patchy and there have been very few sightings from PWS in the last couple of years. The species can be sighted in the conservation plot of PWS.

Lesser Yellownape *Picus chlorolophus* Vieillot, 1818

Lesser Yellownape is widely distributed species, but in Gujarat State, it is found only from Surat-Dangs (Ganpule 2016). The species was reported earlier by Ali (1954–1955), Worah (1991), Bhatt (2004), and Trivedi (2003) from Dangs District. It is a rare resident to the Dangs forests and inhabits moist deciduous forests with bamboo (Ganpule 2016). We could not sight any individual during our surveys in PWS. This species faces a high risk of extinction from the forests of Dangs.

Bar-winged Flycatcher-Shrike *Hemipus picatus* (Sykes, 1832)

Bar-winged Flycatcher-Shrike is a widely distributed species in southern Asia from the Himalaya and hills of southern India and Indonesia. It is mainly insectivorous and often found with mixed-species flock hunting groups in the mixed canopy. The species is recorded from PWS (Ali 1954–55; Worah 1991; Trivedi 2003) and VNP (Shah 2017). It is a rare resident in the Dangs forests and best place to find this species is the Conservation Plot in Bardipada locality. The species is noteworthy because the genus *Hemipus* is considered to be sensitive to forest degradation (Johns 1986; Castelletta et al. 2000).

White-rumped Shama *Copsychus malabaricus* (Scopoli, 1786)

It was previously reported as a resident of Dangs by Ali (1954–1955) and Worah (1991) and from VNP by Singh et al. (2000). The species has a patchy distribution in India (Grimmett et al. 1998) and belongs to the terrestrial insectivore guild. The species is noteworthy because it is susceptible to forest fragmentation (Raman 2001) and resident only to Surat-Dangs in Gujarat State (Ganpule 2016). The species is fairly common in VNP and Conservation Plot, Mahal camp site and Roopgarh fort of PWS.

Bonelli's Eagle *Aquila fasciata* (Vieillot, 1822)

During the vulture census in Dangs, on 3 April 2016, we observed one individual flying, carrying nesting material in its claws. Don Hills are the best habitat for the raptors and probably the species breeds in this locality. Another observation was made during DBF 2018 from Girmal range of PWS on 11 February 2018. Ganpule (2016) has mentioned the species to be a rare resident but is widely distributed with isolated records across the Gujarat State.

Oriental Dwarf Kingfisher Ceyx *erithaca* (Linnaeus, 1758)

Oriental Dwarf Kingfisher is a summer visitor to Himalayan foothills and resident in southwestern India (Grimmett et al. 2014). The species was not recorded from Gujarat until 2014. The first record was made from VNP in Gujarat State (Jat 2015) and later Mistri et al. (2017) reported that the species is possibly breeding visitor in monsoon. Records of the species are mainly from VNP and nearest forests in Surat-Dangs landscape. This might be because of good road connectivity to VNP during the monsoon season whereas PWS is almost cut-off from the main road network due to heavy rain. Also, forest areas are closed in the monsoon seasons for the visitors, making it likely that even though the species is monsoon visitor to PWS, birdwatchers are missing it due to inaccessibility to the slippery and risky stream.

Black-capped Kingfisher *Halcyon pileata* (Boddaert, 1783)

Black-capped Kingfisher was collected only from Sakalpatal, Surat-Dangs by Ali (1954–55). It was not noted elsewhere in Gujarat earlier. Based on the three sightings from Surat-Dangs in 2017 and 2018 (December, January, and March) (Theba 2017b; Khan 2018; Patel 2018a), it is possible that the species is a winter visitor to the landscape. Ganpule (2016) mentioned that the species is an uncommon-to-rare resident and local migrant.

Blue-faced Malkoha *Phaenicophaeus viridirostris* (Jerdon 1840)

One individual of this species was observed by a team member from the group led by NJ in DBF 2016. The individual was sighted in the bamboo thickets nearby the starting point of the trail near Bheskatri range office. On 6 March 1948, Abdulali (1953) shot one individual, but lost the specimen at Pandwa during his ornithological survey. He confirmed the identification through few collected feathers. There has been no other record of the bird from Dangs. One individual has been recorded by Monga & Naoroji (1983) from the forests of Rajpipla from South Gujarat and one historical record from Vadodara (Ali 1954–55). Ganpule (2016) has considered the species as a vagrant and could be occurring in southern Gujarat forests.

Presumed locally extinct species

Red Spurfowl *Galloperdix spadicea* (Gmelin JF, 1789)

Members of the Phasianidae family are highly preferred as a game bird across the WG, especially in the tribal country. Red Spurfowl is highly susceptible to habitat loss and was reported as locally extinct from PWS by Trivedi and Soni (2006). Although, two individuals were observed near Kalibel Village and Sarvar Village by KP on 2 February 2016 and 12 March 2016, respectively. NJ has also sighted the species many times in Savardakasad, Bardipada, Dhulda, and Singhana during the survey of 2012–2013. The species is also recorded from VNP (call heard and recorded) by Patel (2018b), four individuals by Joshi (2014), three individuals by Joshi (2012), and two individuals by Gazdar (2019) who mentioned that *"The birds were clearly seen, their features noted and differences with similar species, such as Grey Junglefowl, ruled out"*. The species still exists in the Surat-Dangs forests in low numbers, but definitely not extinct.

Jungle Bush Quail *Perdicula asiatica* (Latham, 1790)

Jungle Bush Quail has been reported locally extinct from PWS (Trivedi & Soni 2006). The species was also not spotted during field surveys by authors (2012–2018); however, the species was reported on the eBird platform from three different localities of the landscape (Pankaj 2016; Theba 2017a,b). The species faces high hunting pressure and predation of its nests by feral dogs and cats. The species might be extremely rare and recovering, but still highly susceptible to hunting.

White-spotted Fantail *Rhipidura albogularis* (Lesson R, 1831)

This fantail species used to be considered as subspecies of White-throated Fantail *Rhipidura albicollis*. Trivedi & Soni (2006) has also mentioned this species as *Rhipidura albicollis* and stated it to be possibly extinct from PWS. Grimmett et al. (2016) have considered White-spotted Fantail as a distinct species. Contrary to Trivedi & Soni (2006)'s speculation, the species has been reported from various parts of PWS and Dangs in past years and is a common resident of the landscape (Sullivan et al. 2009).

Indian Yellow Tit *Machlolophus aplonotus* (Blyth, 1847)

Parus aplonotus was first described by Blyth (1847). Later, it was treated as a subspecies *Machlolophus xanthogenys aplonotus* (Baker 1922). After that, Ripley (1961) and Ali & Ripley (1983) kept it under the original genus *Parus*, under four subspecies of *Parus xanthogenys*, namely, *xanthogenys, aplonotus, travancoreensis*, & *spilonotus* and Grimmett et al. (1998) also called it as subspecies *Parus xanthogenys aplonotus*. Inskipp et al. (1996) and Kazmierczak & van Perlo (2000), however, treated it as *Parus xanthogenys*. Based on different vocalization, Rasmussen & Anderton (2005) treated it as a separate species *Parus aplonotus* from its conspecific *Parus xanthogenys*. Trivedi & Soni (2006) stated that *Parus xanthogenys,* which is now recognized as *Parus aplonotus* is locally extinct from the PWS, Dangs. The species was reported during the surveys in 2015–16, DBF (2016, 2017) and also from eBird records from 2014–19 (More 2014; Sahajrao 2019).

An unusual record

Masked Shrike *Lanius nubicus* (Lichtenstein MHK, 1823)

A vagrant record of Masked Shrike was recorded from Govaldev forest area (close to PWS) by Hiren Bharti on 18 December 2016. The individual was sighted on multiple occasions, identified and confirmed from multiple photographs. The species was last seen from the locality on 8 January 2017 (Bharti 2017).

Needs confirmation

Blue-bearded Bee-eater *Nyctyornis athertoni* (Jardine & Selby, 1828)

On 8 April 1946, during the survey in Gujarat, Salim Ali heard a distinctive guttural *korr-r-r* call from the foothills of the moist deciduous forest of Medha near Songadh (now Tapi District) (Ali 1954–55). Forest of Medha is continuous with northern forests of Dangs; however, no confirmatory sighting of the species has been reported till date. Further investigation is necessary.

Stork-billed kingfisher *Pelargopsis capensis* (Linnaeus, 1766)

Ali (1954–55) had collected four specimens from three localities from Surat-Dangs; however, he also mentioned that the species is not common in forest streams. There is no record of this species then after and was considered extinct by Trivedi & Soni (2006). Tribes of Dangs forests used sustainable way of fishing earlier using bamboo nets; however, recently we have observed that they also use dynamite blastings for fishing. This change in fishing practice could be the possible reason for the species rarity in the Dangs forests; however, we suspect that the species might be vagrant and only visits during the monsoon. Ganpule (2016) mentioned that the species is rare resident and that the current status is unknown, also probably very rare now in the forests from north to south Gujarat and further study is required.

White-bellied Treepie *Dendrocitta Leucogastra* Gould, 1833

White-bellied Treepie is endemic species, mainly found in WG (Grimmett et al. 2014). It has also been reported from the Surat Dangs and southern part of EG in Andhra Pradesh (Jathar & Rehmani 2006). There is a very old record from Chikalda, Gujarat (McMaster 1871) for this species. Ganpule (2016) mentioned the species as a vagrant. We did not find any recent sighting records. Further investigation is needed to confirm its presence from the landscape.

Possible occurrence

Sri Lanka Frogmouth *Batrachostomus moniliger* Blyth, 1849

Sri Lankan Frogmouth was reported from the southern Western Ghats (Ali 1935; Vijayan 1979; Sugathan 1981; Kannan 1994; Kumara & Singh 2006). Borges (1986) recorded it from Kanara, northern Karnataka and later Giri (2002) extended its northern range further up to Radhanagari WS. Kasambe (2012) extended its range up to Sanjay Gandhi National Park and also suspected that the species could be found up to Surat-Dangs. A sighting of Hodgson's Frogmouth *Batrachostomus hodgsoni* from Shoolpaneshwar was reported by Pilo et al. (1996). But Ganpule (2016) states that how it was separated from Sri Lanka Frogmouth was not reported in that paper and its inclusion is debatable, and this sighting is believed to be of Sri Lanka Frogmouth. But it is interesting to note here that the bird sighting in the debate was caught and examined by the authors (Desai 1996). Dangs forms a promising habitat for frogmouth and we recommend investigating for this species in Surat-Dangs, especially in southern part of the landscape. During our survey, we did not focus on this species and have not listed in this checklist.

Important bird areas in Surat-Dangs landscape

Even though, rich in the avian diversity, small and isolated PAs (here in the landscape, 24km^2 VNP and 160km^2 PWS) are not viable as per the island biogeography concept (Saunders et al. 1991). Trivedi (2003) suggested increasing PAs to a total of around 500km^2 (addition of at least 200km^2 to PWS (Worah 1991) and a corridor between PWS and VNP as one unit) in the landscape. Worah (1991) also suggested identifying even small forest patches that can act as refugia for avian diversity that may help in their dispersal pattern (Raman 2001).

Most Important bird areas in the landscape today are the two designated PAs, PWS and VNP. These PAs are relatively safeguarded and well preserved compared to reserve forests and other parts of the landscape. Another area, a reserve forest, near Gadad Village in the eastern part of the Dangs District, is a vulture breeding site and should be immediately declared as a sanctuary. This area hosts the last stronghold and a breeding population of Long-billed Vulture in the entire district. Also, the area holds one of the last forest patches of wild mangoes. Distribution of the endangered Forest Owlet is not limited to the PAs but widely distributed in Dangs District (Figure 4). Probably, the second-largest population of the species in the country is highly vulnerable to hunting, habitat loss and anthropogenic pressures, but can act as a stronghold for long-term conservation. It is important to declare the areas, where the species is distributed, as PAs or IBA for future conservation measures.

All previous surveys largely focused in and around the PAs, except for the surveys conducted by Ali (1954–55) and Shull (1962). Worah (1991) also suggested that it is necessary to carry out intensive survey in unexplored forest patches in southern Dangs to determine which areas need to be included within the PA network. We have identified 19 localities based on species observed and species collected by Ali (1954–55) and Shull (1962) in Surat-Dangs and plotted them on a map (Figure 5). Here, we have used global position system (GPS) coordinates of the village as locality, as exact locations of the sightings and collection is not mentioned by Ali (1954–55) and Shull (1962). Based on their data, a locality is deemed species rich (SR) if more number of species were collected and/or observed from it. Surprisingly, many SR localities (Mheshkatri, Mahal, Sarwar, and Waghai) are today designated as PAs—PWS and VNP (Figure 5)—but other localities such as Pandva, Galkund, and Malegaon in the south and Medha in the north have almost similar diversity and abundance as the PAs today, but have not been explored in recent years. Based on this, we highly recommend future studies in the identified SR localities outside PAs to evaluate their conservation priority, based on the presence and abundance of endemic and threatened species.

DISCUSSION

According to official records, the numbers of Bengal Tigers recorded from Dangs during different censuses were seven in 1979, nine in 1989, five in 1993, and one in 1997. Since 1997, there are no records of resident population from the landscape (Suchindra 2014). Over the last 75 years, similar to Bengal Tiger, Dangs has seen the local extirpation of many charismatic mammalian

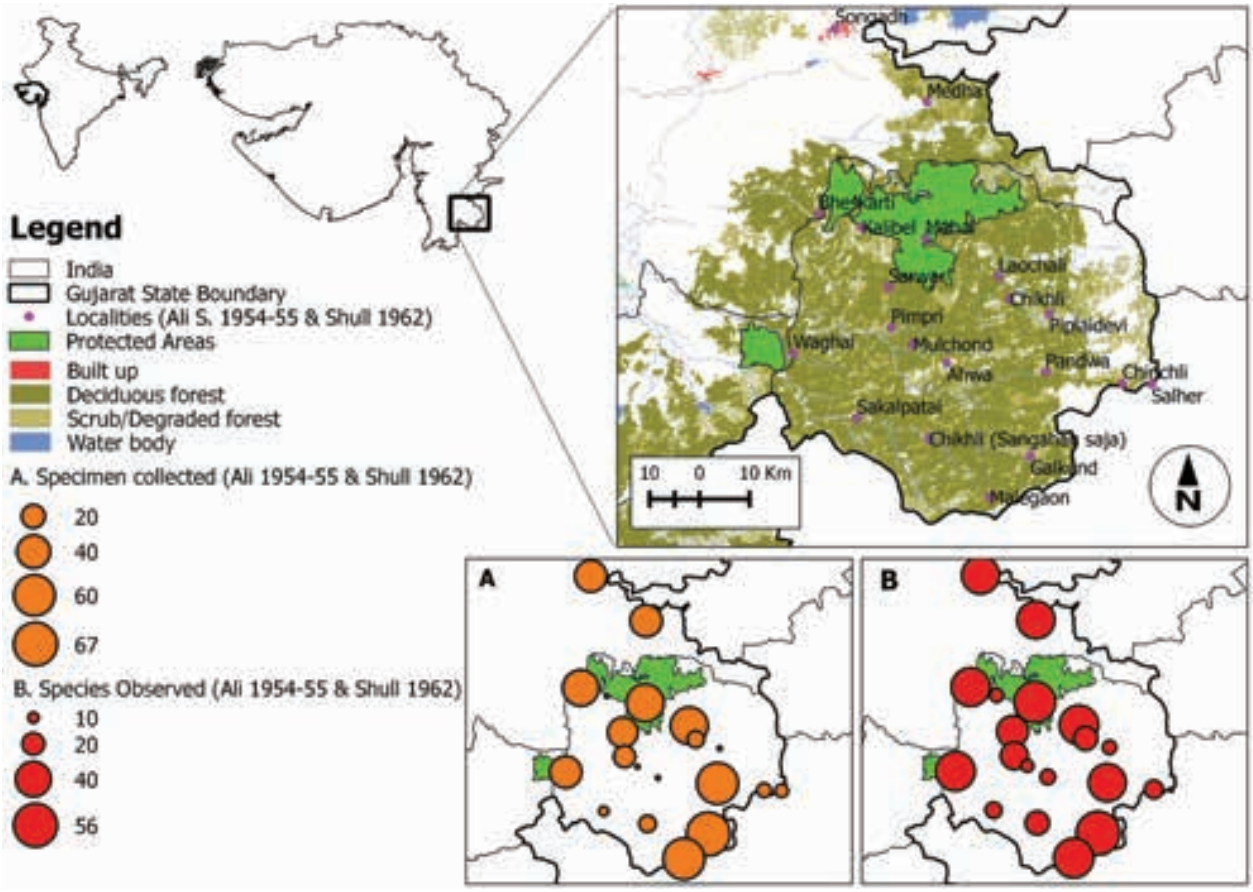

Figure 5. Localities, specimen collected, and species observed from Surat-Dangs by Ali (1954–55) and Shull (1962).

species too, which includes Sloth Bear, Dhole, Sambar Deer, Smooth-coated Otter, Gaur, Dangs Giant Squirrel (race endemic to Dang), and a reptilian species Marsh Crocodile (Worah 1991; Singh et al. 2000). The remaining large-bodied mammalian species, Four-horned Antelope, Barking Deer, and Chital, are highly sparse and in low densities (Suchindra 2014). Due to depletion of mammal population, birds became a prime choice of hunting for locals (Chowdhary 2016). Hunting birds and small mammals with rubber slingshot and traps is still common. Also, cattle grazing in the protected area, teak monoculture by the forest department and illegal trade of *Psittacula spp*. pose a considerable threat to the avifauna in the landscape.

Apart from the studies done by Ali (1954–55) and Shull (1962), other studies were focused on the two protected areas (PWS and VNP) of the district. Future studies need to be focused on SR localities identified in the landscape. Also, survey during monsoon season has been ignored and future surveys might lead to interesting sightings (e.g., rails, crakes). The landscape also holds promising premise for raptor ecology studies. Future studies are needed to understand population dynamics of species that are threatened and endemic to the landscape. We suggest updating the checklist at least every two or three years, which will help add more species to the checklist and determine the exact status of the species in the landscape.

Re-report of the bird species from the landscape suggest that there must be special investigation for other species, including mammals which has been reported as locally extinct. They might be present in very low density, are sparce and highly elusive to have come across any researchers/naturalists to re-report them. Advanced methodology such as camera trap (for large bodied mammals), live trap (for small mammals) and genetic tools using non-invasive samples such as scat (Thatte et al. 2018) and shed hairs (Khan et al. 2020), which are reliable and affordable to generate data, can be used to identify species' presence. Recent report of Madras Tree Shrew *Anathana ellioti* (Patel et al. 2020) and new records of Blanford's Wood Rat *Madromys blanfordi* (Patel et al. 2018) from the landscape suggest that there could be higher diversity of small mammals than

previously reported and could be contributing to diet of 45 species of carnivorous birds (especially for Owls) in the landscape. Diversity of avifauna, small mammals and presence of large carnivores could help in identifying new potential PAs in more ecological sense.

Long-term and regular monitoring of diversity and population can help to improve the wildlife population. Furthermore, citizen science initiative such as DBF has proved to be a successful exercise to monitor avian diversity of the area and to spread awareness among Dangi people. It has also led to the alternative livelihood option for locals in the form of eco-tourism. Locals trained as bird guides will enhance the sense of ownership for supporting wildlife monitoring and its protection.

Surat-Dangs forests fulfills criteria A1, A2, & A3 of Birdlife International necessary for the declaration of Important Bird Area. Designation of IBA will be a very crucial and much-needed accolade to Surat-Dangs, which will pave the possible way for many future conservation endeavors.

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Identification of a unique barb from the dorsal body contour feathers of the Indian Pitta *Pitta brachyura* (Aves: Passeriformes: Pittidae)

-- Prateek Dey, Swapna Devi Ray, Sanjeev Kumaar Sharma, Padmanabhan Pramod, Ram Pratap Singh, Pp. 18781-18791

We regret to withdraw our manuscript entitled “Identification of a unique barb from the dorsal body contour feathers of the Indian Pitta *Pitta brachyura* (Aves: Passeriformes: Pittidae)" published in the Journal of Threatened Taxa [(Vol. 13 No. 7 (2021)] due to an inadvertent error in the Map of India.

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COMMUNICATION

Underestimated diversity of *Cnemaspis* Strauch, 1887 (Sauria: Gekkonidae) on karst landscapes in Sarawak, East Malaysia, Borneo

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Abstract: The paraphyletic group of Old World rock gecko genus *Cnemaspis*, currently comprises ~180 described species from Africa and Asia. The south-east Asian clade with 63 described species, is most diverse on the Thai-Malay Peninsula, with just five species known from Borneo, an island biodiversity hotspot. Karst regions are known as centres for species endemism, and vast areas of caves and karst exist across northern Borneo. Fieldwork from 2017 to 2020 recovered additional undescribed species of *Cnemaspis* from areas of karst forests in western and northern Sarawak. These discoveries emphasize the importance of preserving areas of limestone karst within rainforest areas for maintaining species diversity, as well as accelerating research on documenting the biota.

Keywords: Biodiversity, rock gecko, systematics.

Bahasa Malaysia: Kumpulan paraphyletic cicak batu genus *Cnemaspis* dari Dunia Lama, kini dianggarkan mempunyai ~180 spesis dikenal pasti dari Afrika dan Asia. Klad Asia tenggara dengan 63 spesis terhurai, dilihat lebih pelbagai di semenanjung Thai-Malay, dengan hanya lima spesis dikenal pasti dari Borneo, sebuah pulau kaya dengan kepelbagaian hidupan. Kawasan batu kapur diketahui sebagai kawasan tumpuan spesis endemik, dengan jumlah bilangan kawasan gua dan batu kapur yang besar di utara Borneo. Kerja lapangan daripada 2017 hingga 2020 telah menambahkan bilangan spesis Cnemaspis dari kawasan hutan batu kapur di barat dan utara Sarawak. Penemuan ini menekankan kepentingan memelihara kawasan batu kapur dalam hutan hujan tropika untuk menjaga kepelbagaian spesis, serta meningkatkan kajian dan dokumentasi biota.

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INTRODUCTION

Sarawak State of East Malaysia, located on the northwestern region of the island Borneo, can be divided into two mineralization zones, corresponding to geological provinces, namely, West Sarawak that hosts important metalliferous mineral deposits, which geologically forms part of the Sunda Shield; and central-northern Sarawak, which is renowned for fossil fuels, such as oil, gas and coal deposits. Limestone outcrops cover 520km^2 (or 0.4%) of Sarawak, and are reported to be shallow marine deposits ranging from Upper Carboniferous to Miocene (Gendang et al. 2008). Older limestone deposits are located in western Sarawak, while the younger one are found in central and northern Sarawak. Karstic regions have been regarded as biodiversity reservoirs that can be used as stock for repopulating degraded environments during ecosystem reassembly (Schilthuizen 2004). Past research conducted on karst formations and adjacent limestone forests in the Sundas have resulted in improved knowledge of endemic species of flora and invertebrates, as well as better appreciation of their endemicity. Microendemic karst-dwelling species of squamate reptiles too have been identified and described from such landscapes (Ellis & Pauwels 2012; Grismer et al. 2015).

In Borneo, recent discoveries of lizard species have been made, especially in areas with forest cover, including species of *Cnemaspis* (Grismer & Chan 2009; Kurita et al. 2017), *Cyrtodactylus* (Hayden et al. 2019), and *Lygosoma* (Karin et al. 2018), highlighting the underestimated nature of the diversity. At the same time, the landscape of Borneo is experiencing rapid change through deforestation from activities such as large- to small-scale agriculture and colonization, unsustainable logging, fires, mining and construction of infrastructure (Bennet 2017), resulting in the degradation of the ecosystem. *Cnemaspis* Strauch, 1887 is a lizard genus allocated to the family Gekkonidae, comprising ~180 described species from tropical Africa and Asia (Uetz et al. 2021), making it one of the most speciose Old World gekkonid genera. As currently constituted, the genus has been shown to be polyphyletic (Gamble et al. 2012; Grismer et al. 2014). Members of the genus in Asia occupy habitats ranging from lowland dipterocarp forests to primary and old-growth forests, often within karst, granite or sandstone landscapes (Das & Bauer 1998; Iskandar et al. 2017).

The south-east Asian *Cnemaspis* group has been reported from areas of Myanmar, Thailand, Vietnam, Cambodia, Laos, Peninsular Malaysia, Singapore, Sumatra, Borneo, and Java, in addition to numerous small and mid-sized islands off some of these landmasses. With its distribution extending from the subtropical eastern Himalaya and Indo-China, to tropical areas of Sundaland, the highest diversity is encountered on the Thai-Malay Peninsula (Kurita et al. 2017). Phylogenetic analyses of south-east Asian *Cnemaspis* have revealed two divergent lineages: the southern Vietnamese insular endemics and a lineage containing three major clades referred to as the Pattani, northern Sunda, and southern Sunda clades distributed sporadically along the northern, western and southern edges of the Sunda Shelf, extending from southern Vietnam, Cambodia and Thailand, southward through the Thai-Malay Peninsula, to Borneo (Grismer et al. 2014, 2015; Kurita et al. 2017; Wood et al. 2017). The Pattani clade, restricted to the southernmost portion of peninsular Thailand, is sister to the northern Sunda and southern Sunda sister clades. The northern Sunda clade extends from Vietnam to central Peninsular Malaysia, while the southern Sunda clade extends from southern Peninsular Malaysia and Singapore, eastward through the Seribuat, Anambas, and Natuna archipelagos to northwestern Borneo.

The first member of the genus *Cnemaspis* on Borneo was reported by Gray (1845), described as *Heteronata kendallii*, based on two specimens presented to the British Museum of Natural History by Captain Edward Belcher, with locality given simply as "Borneo". Smith (1925) described the second Bornean species, *Gonatodes nigridius*, from "Mt. Gading" (= Gunung Gading). Dring (1979) subsequently discovered that one of Gray's syntypes was a juvenile *Cnemaspis nigridia* (Smith, 1925), and designated the other as the lectotype of *Cnemaspis kendallii*. Das & Bauer (1998) described *Cnemaspis dringi* from Labang Camp, Bintulu, Sarawak and Grismer & Chan (2009) recorded the first karst-endemic species on Borneo, *Cnemaspis paripari* from Gua Pari Pari (Fairy Cave) and Gua Angin (Wind Cave), in the Bau region of Sarawak. The most recent discovery was by Kurita et al. (2017), who described *Cnemaspis leucura* from Gunung Penrissen, Sarawak. These five species currently represent the known diversity of the genus on Borneo. Bornean *Cnemaspis* are represented by two major lineages (the *nigridia* group and the *kendallii* group); however, Kurita et al. (2017) recovered a basal polytomy of *Cnemaspis dringi*, the *nigridia* group, and the *kendallii* group, suggesting multiple origins of the Bornean *Cnemaspis*.

During recent fieldwork, we discovered additional populations of *Cnemaspis* in areas of limestone formations which, on the basis of morphological

characters and phylogenetic divergence, we regard as new species. We here describe the distribution and habitats of these geckos.

MATERIALS AND METHOD

Inventories were conducted between 2017 and 2020, and collections were made during both day and night at a number of localities in Sarawak. A hand-held Global Positioning System Garmin, GPSMap 76CS receiver (datum WGS 84) was used for georeferencing. We used Google Maps and Google Earth Pro to identify areas for sampling, prioritizing the presence of intact vegetation with a greater possibility of the occurrence of members of the genus. Sites inspected included national parks, nature reserves and other areas within karst formations, as well as non-karst areas. The visual encounter survey method was used to locate individuals, and macro- and micro-habitat features were identified. Specimens were photographed using a Nikon D600 DSLR camera and 105mm Micro-Nikkor f/2.8 D lens, illuminated by a speedlight flash unit (SB800), using a Lastolyte softbox. Temperature and humidity of the study sites were recorded using CENTER 315 humidity temperature meter. Specimens were collected manually, euthanized with the use of sodium pentobarbital, fixed in 10% buffered formalin prior to storage in 70% ethanol in the collection of the museum of the Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak (UNIMAS). Tissue samples were taken and preserved in 95% ethanol for DNA analysis.

Study sites

We obtained research permit for collection and permission to enter national parks and conduct studies from the Sarawak Forest Department for multiple localities. Habitat associations of members of the

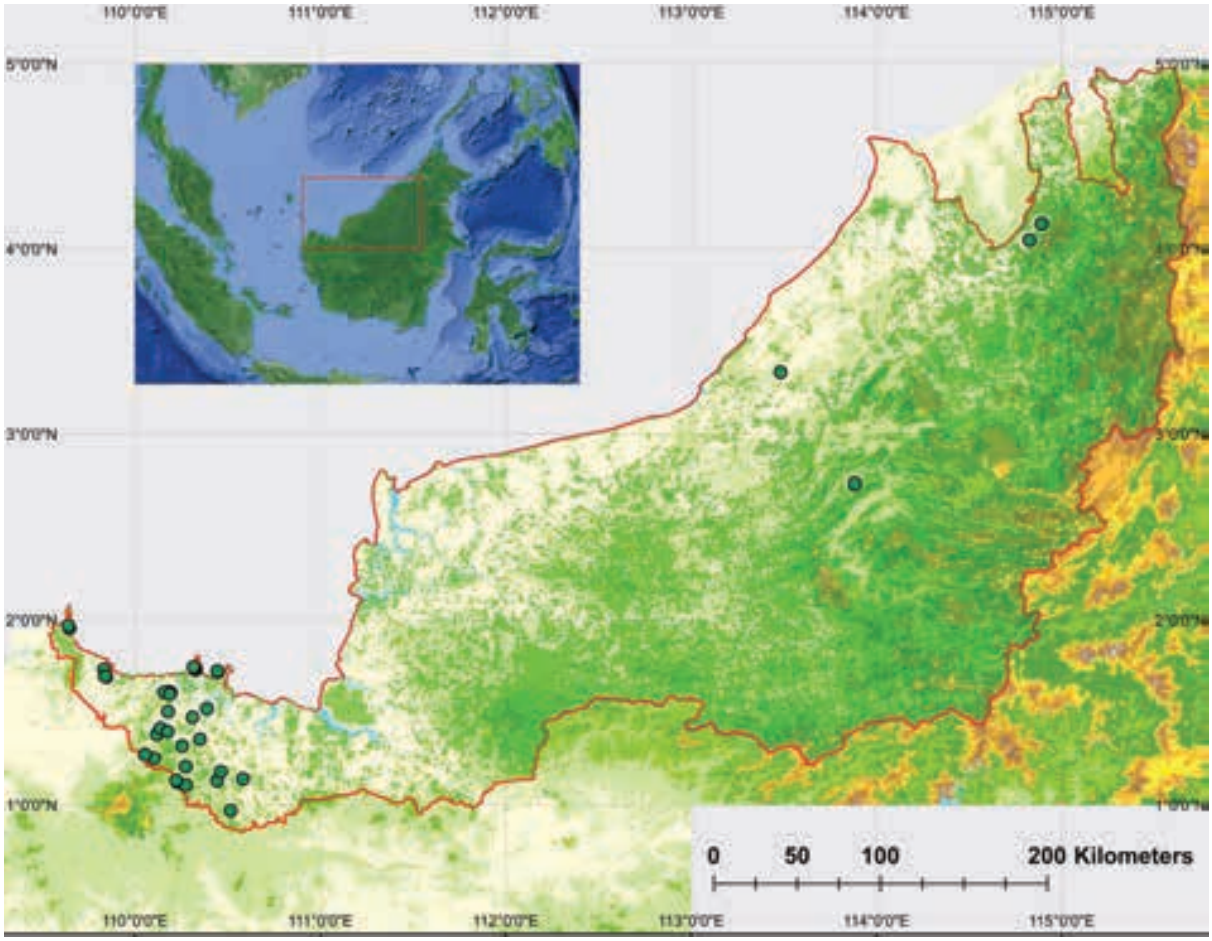

Image 1. Forest cover and records of *Cnemaspis* species in Sarawak, East Malaysia. Insert: Map of Borneo and adjacent regions in south-east Asia showing the enlarged area below. Vector tile of Sarawak Forest Cover 2019 by Sarvision. Updated as of October 2020. Developed for Heart of Borneo (HoB) initiative by WWF-Netherlands, WWF-Indonesia and WWF-Malaysia.

lineage and habitat assessments were conducted by day, while collections of specimens were conducted between 2000–2300 h. A total of 27 areas were surveyed during the present study (Table 1), including primary and secondary forests. Sites included the Kayan Plateau sandstone of Bako National Park; Kayan sandstone of Gunung Gading National Park, the Serapi Range, Kubah National Park, Santubong National Park, and on the Pedawan Formation of Gunung Penrissen. The Bau Limestone which includes karst towers and formations, such as Fairy Cave and Wind Cave Nature Reserve, and Dered Krian National Park; Kedadom and Pedawan limestone formations in Siburan and Serian District, consisting of multiple karst hills and caves, such as Gua Raya, Gua Rabus, Gua Silabur, Gua Simadang and Gua Sireh; the Belaga Formation of central Sarawak, Pelagus National Park; the Nyalau/Sibuti Formation of Niah National Park; and also the Melinau Limestone and Mulu Formation of the Gunung Mulu National Park, northern Sarawak.

Limestone hills are characteristically steep-sided, with subvertical to overhanging cliffs. The base of limestone hills exhibit deep horizontal notches or undercuts due to dissolution by streams, groundwater or swamp water, and the collapse of the limestone cliffs contributing to the reduction in size of limestone hills. Mazed with numerous caverns and cave systems, limestone hills range in height and size, and provide multiple microclimates.

RESULTS

In western Sarawak, habitats occupied by *Cnemaspis* are present both within the protected areas network (such as national parks) and in unprotected ones. Additional populations were recorded within the Siburan and Serian districts. The deposits of Kedadom and Pedawan formations are of Late Jurassic – Late Cretaceous age. The karst towers of these regions reach elevation of approximately 700m, and are dominated by mesophytic flora. Streams, often originate from these formations. Some of the karstic areas are bounded by human activities such as orchards and plantations, limestone mining and land development. Individuals were found usually on ground level spatially constrained to an area with multiple degree of surfaces. In northern Sarawak, the habitat of *Cnemaspis* is located within the Melinau Limestone formation, within the protected boundaries of Gunung Mulu National Park. Deposited in the Eocene to the Miocene, this geological formation reaches a height of approximately 1,700m. Specimens were found at ground level, on stalactites and on walls of the cave entrance.

Substrate identified associated with *Cnemaspis* can be classified into granite, limestone, sandstone and vegetation. *Cnemaspis kendallii* is here considered the most generalized species, being observed on multiple substrates, and showing overlapping distribution (= syntopic) with *C. nigridia*, *C. paripari*, and *C. leucura*. *C. kendallii* may persist in disturbed areas such as the detached forest patch of Sama Jaya Nature Reserve, which serves as a rainforest park in an urban setting. Covering 38ha, the population is disconnected from the major forest region. Another example of persistency is observed in the population of *C. paripari* from the Fairy Cave Nature Reserve which occurs as an isolated karst hill measuring about 4ha, detached from the major Bau Limestone formation by 800 m of lowland. Members of the genus are often found syntopic with other gecko species, especially Bent toed geckos, *Cyrtodactylus*.

Rock crevices act as shelters into which geckos typically retreat when threatened. Furthermore, crevices also serve as a nursery for eggs. Egg-clutches were observed in pairs, embedded within depressions of mineral formations in such moisture-laden microhabitats. For the first two species, communal nesting, as evidenced from multiple egg-scars on rocks, was noticed. Habitat descriptions of Bornean *Cnemaspis* are summarised in Table 2.

DISCUSSION

The discovery of undescribed *Cnemaspis* reveals the poorly-known nature of the herpetofauna of Borneo. Based on surveys and satellite imagery, sites of occurrence tend to be isolated and restricted to mineral formations and intact secondary to primary forests. Although environmental conversion can occur naturally, human activities have intensified the decline of many habitats. Major conservation concerns that can be identified from this study are major and minor agricultural practices, mining of limestone for industry and deforestation. These factors seriously influence the quality and extant of *Cnemaspis* habitats in Sarawak.

Populations of *Cnemaspis* geckos are fragmented by human intervention. The hills of the Bau Limestone stretching to the Pedawan formation and along with Kedadom and Sadong formations comprise karst outcrops of which some parts are mined for industrial uses such as cement production. Shifting agriculture and

Table 1. Study sites in Sarawak State, East Malaysia (Borneo), with reference to geological formations and general habitat descriptions. Asterix indicates locality where species of *Cnemaspis* have been recorded.

	Localities, Division	Coordinates	Geological Formation and General Habitat Type
1*	Bako National Park, Kuching	1.7179°N, 110.446°E	Plateau Sandstone Formation ~ 200m. Coastal forest, swamp forest, mixed dipterocarp forest
2*	Bengoh Range, Bau	1.252°N, 110.102°E	Kayan Sandstone Formation ~ 900m. Mixed dipterocarp forest, with agriculture and human settlements on foothills
3*	Borneo Highlands at Gunung Penrissen, Padawan	1.135°N, 110.221°E	Kayan Sandstone Formation ~ 1,000m. Mixed dipterocarp forest, submontane forest
4*	Dered Krian National Park, Bau	1.3802°N, 110.163°E	Bau Limestone Formation ~ 400m. Karst formation, dominated by herbaceous plants and mid-sized trees; conversion to commercial plantation on foothills
5*	Gua Angin, Bau	1.416°N, 110.133°E	Bau Limestone Formation ~ 50m. Cave systems, dominated by herbaceous plants and mid-sized trees
6*	Gua Pari Pari, Bau	1.381°N, 110.117°E	Bau Limestone Formation ~ 250m. Cave systems, dominated by herbaceous plants and mid-sized trees
7*	Gua Rabus, Temurang, Padawan	1.207°N, 110.273°E	Pedawan Formation ~ 500m. Cave system dominated by herbaceous plants and mid-sized tree; natural vegetation hemmed by horticulture
8	Gua Raya, Kampung Chupak, Serian	1.285°N, 110.429°E	Sadong Formation ~ 600m. Abandoned bird-nest harvesting operations in cave system, broken plank walks, dominated by herbaceous plants and mid-sized trees
9*	Gua Silabur, Lobang Batu, Tebakang, Serian	0.969°N, 110.516°E	Sadong Formation ~ 50m. Cave system dominated by herbaceous plants to mid-sized trees and bounded by local horticulture.
10*	Gua Simadang, Temurang, Padawan	1.207°N, 110.274°E	Pedawan Formation ~ 500m. Cave system dominated by herbaceous plants to mid-sized trees and bounded by local horticulture.
11*	Gua Sireh, Kampung Bantang, Serian	1.180°N, 110.463°E	Sadong Formation ~ 350m. Archaeological site. Cave system dominated by herbaceous plants and mid-sized trees, hemmed in by horticulture
12*	Gunung Gading National Park, Lundu	1.691°N, 109.845°E	Gading Formation ~ 850m. Mixed dipterocarp forest, with granite boulders and scree at foothills
13*	Kampung Mambong, Siburan	1.355°N, 110.351°E	Bau Limestone Formation ~ 100m. Weathered limestone hills, dominated by herbaceous plants and mid-sized trees, hemmed in by horticulture
14*	Kampung Puak, Bau	1.358°N, 110.141°E	Bau Limestone Formation ~ 400m. South of Dered Krian and Fairy Cave, its sharp limestone ridges dominated by herbaceous vegetation and mid-sized trees; small stream present
15*	Kampung Skio, Bau	1.396°N, 110.176°E	Bau Limestone Formation ~ 250m. Outcrops connected to Dered Krian formation; cave opening with small stream
16*	Kubah National Park, Kuching	1.612°N, 110.196°E	Kayan Sandstone Formation ~ 850m. Mixed dipterocarp forest; forest stream originate from upper elevation
17*	Lambir Hills National Park, Miri	4.198°N, 114.042°E	Lambir Formation ~ 450m. Mixed dipterocarp forest, with steep slope
18*	Limestone Hills of Jambusan-Samadang, Siburan	1.319°N, 110.255°E	Pedawan Formation ~ 300m. Karst formation, bounded by river and oil palm plantation
19*	Limestone hills, Serian-Tebedu, Serian	1.130°N, 110.444°E	Kedadom Formation ~ 300m. Karst formation, dominated by herbaceous vegetation; presence of small stream
20*	Gunung Mulu National Park, Miri	4.041°N, 114.812°E	Melinau Limestone Formation ~ 1,750 m; Mulu Formation ~2,376m. Massive karst formation, submetamorphic slates and hard sandstones, mixed dipterocarp forests at points of sampling; other vegetation types at higher elevations or other sites within the National Park
21	Nanga Pelagus, Belaga	2.169°N, 113.056°E	Pelagus Formation Low sandstone hills; small forest streams
22	Niah National Park, Miri	3.824°N, 113.761°E	Subis Limestone ~ 350m. Karst formation within lowland mixed dipeterocarp forest
23	Pelagus National Park, Belaga	2.188°N, 113.056°E	Pelagus Formation Mixed dipterocarp forest at edge of Rajang River
24*	Ranchan Pool Forest, Serian	1.143°N, 110.584°E	Sadong Formation ~ 800m. Sandstone hill with forest stream, frequented as recreational area
25*	Sama Jaya Nature Reserve, Kuching	1.522°N, 110.387°E	Alluvium flat ~ 0m. Forest reserve within city of Kuching, comprising Kerangas (Bornean heath) forests with blackwaters and mixed dipterocarp forest
26*	Gunung Santubong National Park, Kuching	1.743°N, 110.317°E	Kayan Sandstone Formation ~ 800m. Mixed dipterocarp forest, with streams and waterfalls
27	Tinbarap Oil Palm Plantation, Miri	4.055°N, 114.238°E	High Value Conservation forest ~ 0m. Conserved forest patch; blackwater swamp forest

Table 2. Summary of *Cnemaspis* habitat use and activity on Borneo.

Species	Active period	Preferred substrate			
		Granite	Limestone	Sandstone	Vegetation
kendallii	Diurnal	+	+	+	+
nigridia	Nocturnal	+	-	-	-
dringi	NA	NA	NA	NA	+
paripari	Nocturnal	-	+	-	-
leucura	Nocturnal	-	-	-	-
Species 1	Nocturnal	-	+	-	-
Species 2	Nocturnal	-	+	-	-
Species 3	Nocturnal	-	+	-	-

Image 2. Karsts habitat for *Cnemaspis* in Sarawak: Top and bottom left—limestone hills in Serian District | Top right—egg scars within crevices of limestone formation | Bottom right—*Cnemaspis* gecko on limestone substrate. © Izneil Nashriq

mining activities are both widespread and sometimes intense in Sarawak, which, if not mitigated or done sustainably, not only affect these geckos, but in a wider context, result in loss of biological diversity as a whole.

CONCLUSION

The accretion of species of *Cnemaspis* on Borneo has been somewhat sluggish, starting with *C. kendallii* in 1845, *C. nigridia* in 1925, *C. dringi* in 1998, *C. paripari* in 2009, and most recently, *C. leucura* in 2017. The effort of locating specimens may be thwarted by their occupancy of relatively inaccessible areas and microhabitats,

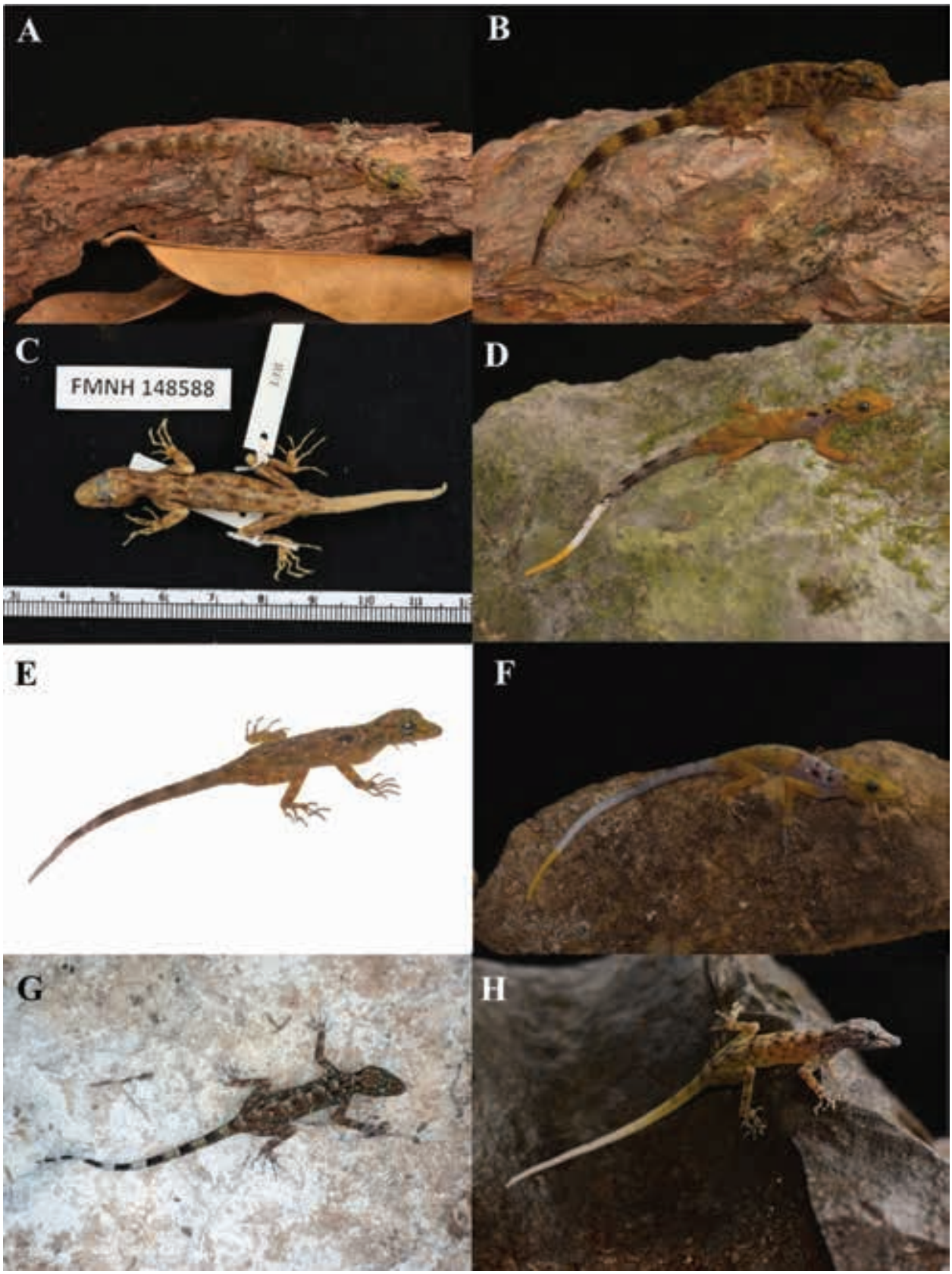

Image 3. Bornean species of rock geckos. A—*Cnemaspis kendallii* | B—*Cnemaspis nigridia* | C—*Cnemaspis dringi* | D—*Cnemaspis paripari* | E—*Cnemaspis leucura* | F—*Cnemaspis* Sp. 1 | G—*Cnemaspis* Sp. 2 | H—*Cnemaspis* Sp. 3. © A, B, D, F, H—Indraneil Das; C—Joshua Matta; E—Pui Yong Min; G—Hayden Davis

besides the ecologically cryptic nature of these species. In addition to the described species, four from western Sarawak, and one in central Sarawak, morphological and genetical data reveal the existence of three additional species from western and northern Sarawak. Mineral formations of Sarawak are home to a disproportionate number of *Cnemaspis*, all except one showing rupicolous adaptations. Only *C. kendallii* inhabits forested areas, and is sylvicolous. On the other hand, *C. nigridia* is restricted to granite formations; *C. paripari* endemic to limestone formations; and *C. leucura* from sandstone formations. All three undescribed species reported in this study inhabit separate limestone formations. This brings the number of species to a total of eight occurring on the island of Borneo, an increase of 60% of the fauna.

The study was focused largely in western Sarawak. The formations in western Sarawak are relatively more accessible compared to those of central and northern Sarawak. Future efforts should be directed in finding species of *Cnemaspis* in these latter areas, especially along regions of limestone karst.

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COMMUNICATION

Aborichthys barapensis, a new species of river loach (Cypriniformes: Nemacheilidae) from Arunachal Pradesh, the eastern Himalaya, India

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Abstract: A new species of nemachilid loach *Aborichthys barapensis,* is described based on two adult specimens (91 and 97 mm SL) from the Barap Stream (a tributary of the Brahmaputra River basin) in the southeastern most part of the state of Arunachal Pradesh bordering Myanmar. The new species is distinguished from its congeners in having a narrow black basicaudal bar without a black ocellus on the upper end (vs. present); and in having a very low dorsal and ventral adipose crests (vs. prominent; absent in *A. waikhomi*). The new species is further distinguished from its congeners by the following combination of characters: body with 24–26 oblique bars along the flank; interspace narrower than bars on body; moderately rounded caudal fin with five distinct black to brown cross bars; vent closer to the caudal-fin base (44.1–45.1 % standard length) than to snout tip.

Keywords: Barap Stream, northeastern India, upper Brahmaputra River basin.

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Author contributions: Both authors have equally contributed in designing, data recording and analysis, interpretation, drafting of manuscripts, critical review and revisions.

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INTRODUCTION

Members of the genus *Aborichthys* belonging to family Nemacheilidae, is an elongate and slender bodied bottom dwelling freshwater loach, that inhabits fast flowing water of mountain rivers, streams, drainages of Ganga-Brahmaputra River, and is endemic to the eastern Himalaya. They are characterized by having vent situated close behind pectoral girdle, dorsal fin at vertical originated slightly behind pelvic fin-origin; narrow oblique bars on body; a black ocellus at upper extremity of caudal-fin base (but here absent), and rounded or truncate caudal fin marked with concentric rings or irregular black patches, and all fins considerably separated (Chaudhuri 1913; Kosygin 2019; Shangningam 2019). So far, nine species of *Aborichthys* are recognized as valid, whose diversity is mostly confined to Brahmaputra River basins in Arunachal Pradesh, northeastern India, and its distribution extends to Bhutan and Putao in Myanmar (Chaudhuri 1913, 1919; Hora 1925; Talwar & Jhingran 1991; Shangningam et al. 2019).

The first species *Aborichthys boutanensis* (Griffith & McClelland, 1842) previously named *Cobitis boutanensis* known from the neighboring country Bhutan, when the genus was not established. Later, Thoni & Hart (2015) considered it to be a member of *Aborichthys*. The genus was first erected by Chaudhuri (1913) assigning *A. kempi* as the type species collected by Mr. S.W. Kemp from Sirpo and Egar stream near Rottung and Renging village, Arunachal Pradesh in the east and has since remained monotypic until Hora (1921) described *A. elongatus* from the Riang River (Brahmaputra Basin), Darjeeling (West Bengal) in the west. Thereafter, Hora (1925) further contributed another species *Aborichthys garoensis* from Tura, Garo Hills, Assam (now Meghalaya) in the southwest, followed by Barman (1984) who added *Aborichthys tikaderi* from Namdapha Wildlife Sanctuary, Changlang District in the southeastern part of Arunachal Pradesh. Over the last one decade, six more sympatric species have been described from the upper Brahmaputra River basins in Arunachal Pradesh, viz., *Aborichthys waikhomi* (Kosygin, 2012) from Bulbulia Stream near Bulbulia, a tributary of Noa-Dihing River, Namdapha, Changlang District in the east; *A. kailasi* and *A. pangensis* (Shangningam et al., 2019) from Pange River, Ziro, Lower Subansiri District in the west; and *A. iphipaniensis* (Kosygin et al., 2019) from Iphipani River, Roing, Lower Dibang Valley District in the east.

While conducting an ichthyological survey in Barap River near Lazu Village in Tirap District, southeastern most part of the Arunachal Pradesh bordering Myanmar, we came across two adult specimens of *Aborichthys*. Later, examination revealed that it belonged to an unnamed species of *Aborichthys*, which is described herein.

MATERIAL AND METHODS

Sampling of fishes was done by using caste net with (2 m diameter and 7 mm meshes) in a small and shallow stream (depth ca. 10–30 cm), locally known as 'Barap' (26.898 N & 95.560 E, 1,020 m). The collected specimens were freshly preserved in 10 % formaldehyde in the beginning to hold body coloration, and then transferred to 70 % ethanol after noting down its color. Measurement was made point to point with digital caliper nearest to 0.1 mm. Counts and measurements were made on the left side of specimens following Keskar et al. (2015) except self-explanatory characters, i.e., distances from: dorsal to caudal base, pectoral to pelvic, pectoral to anal, pectoral to vent, pelvic to anal, pelvic to vent, vent to anal, vent to caudal-fin base, anal to caudal base, anal-fin tip to caudal-fin base, vent to anal distance, vent to pelvic distance, mouth length, mouth width, length of medial, lateral and maxillary barbels, caudal peduncle length/caudal peduncle depth, and mouth length/mouth width. Mouth width was measured from posterior extremity of one corner to another and length medially from anterior margin of upper lip to level of posterior margin of lower lip.

Subunits of head are expressed as proportions of lateral head length. Fin rays, cephalic lateralis system, and lateral line pores were counted under a stereo-zoom transmitted light microscope (Magnus MS 24) following Kottelat (1990) except an additional: nasal pores (close to nare), antero-nasal pores (scattered pores in front of nares), pre-nasal pores (two pores situated each side between nare and outer rostral barbel base), supramaxillary pores (running along base of outer rostral barbel to posterior margin of cheek; Figure 1b). Lateral line sensory pores of three patterns – single, double (closely set), or triple (triangular and closely set), counted each pore as one (Figure 2). Three forms of oblique bars along flank (regular, bifurcated or fused). Bifurcated bars – those single bars bifurcate at the top along the dorso-lateral margin of the body, and counted as one; fused bars – those paired bars fused or joined at the top along dorso-lateral margin of the body, and counted as two. Asterisk mark (*) after a value indicates holotype.

The holotype and paratype are deposited in Estuarine Biology Research Centre (EBRC), ZSI, Gopalpur, India and Dera Natung Government College (DNGC) Itanagar, respectively for future reference.

RESULTS

Aborichthys barapensis sp. nov.

(Images 1,3; Figures 1,2)

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Type material

Holotype: EBRC/ZSI/F-12608, 08.iii.2020, 97mm SL, from small diverted course of Barap Stream (Brahmaputra River basin) near Lazu Village, Arunachal Pradesh, 26.898758 N & 95.560656E, 1,020 m, coll. P. Nanda & Nali Kholia Rangsong.

Paratypes: DNGC F–02, 1 specimen, 91 mm SL, same information as in holotype.

Diagnosis

The new species is diagnosed from its congeners in having a narrow black basicaudal bar without a black ocellus on the upper end (vs. present); and in having a very low dorsal and ventral adipose crests (vs. prominent; absent in *A. waikhomi*). The new species is further distinguished from its congeners by the following combination of characters: body with 24–26 oblique bars along the flank; interspace mostly narrower than bars on body; moderately rounded caudal fin with five distinct black to brown cross bars; vent closer to the caudal-fin base (44.1–45.1 % SL) than to snout tip.

Description

For general appearance see Image 1. Morphometric data are presented in Table 1. Body elongate and slender, body between pectoral fin and posterior tip of dorsal fin cylindrical in cross section and thereafter compressed posteriorly. Body deepest at dorsal-fin origin, depth equal its width. Dorsal profile evenly rising from snout tip to occiput, then horizontal up to point at vertical through tip of anal fin, there after very gently radiating away, due to very low and short dorsal adipose crest, confluent with caudal fin. Ventral profile almost horizontal to anal-fin origin, then gently rising up to its posterior end, thereafter very gently radiating away due to ventral adipose crest, confluent with caudal fin, ventral adipose crest much lower than dorsal, adipose crests much lower in paratype (Image 1a, 2).

Head triangular when viewed dorsally and depressed, longer than caudal fin, width greater than height, length 5.1*–5.2 times its standard length, but almost equal to pectoral and pelvic fin length, and depth almost equal to length of dorsal-fin base, lateral head length longer than dorsal, dorsal profile evenly slope, and ventral flattened. Snout obtusely pointed in dorsal view. Eyes moderate (11.2–12.4 % HL), dorsally situated, closer to tip of snout than to posterior extremity of opercle, not visible from ventral, 2.1*–2.8 times smaller than inter-orbital space. Nostril closer to eye than to tip of snout, nares separated by triangular membrane flap dividing it into two parts; anterior nare tubular, attached with membrane flap, membrane flap raised up and slightly twisted postero-laterally, and posterior nare roughly triangular. Three pairs of barbels; one pair maxillary and two pairs of rostral, longer than eye, medial and maxillary barbel almost equal, lateral barbel slightly longer. Medial rostral barbel extending anterior margin of knob on lower lip in holotype, whereas reaching posterior margin of knob in paratype, adpressed lateral rostral barbel reaching or closer to maxillary barbel base, maxillary barbel at

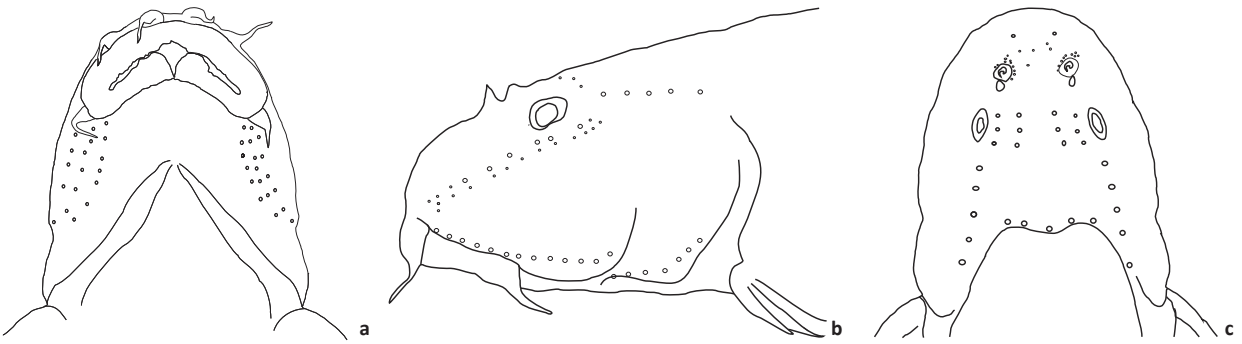

Figure 1. Sketch diagram of *Aborichthys barapensis* sp. nov., EBRC/ZSI/F-12608, holotype, 97.0mm SL, ventral, lateral and dorsal views, showing sensory pores on cephalic lateralis system: a—preoperculo-mandibular | b—infraorbital, suprapremaxillary, subopercular | c—pre-nasal, antero-nasal, nasal, supraorbital, temporal, and supratemporal.

Image 1. ***Aborichthys barapensis*** **sp. nov., EBRC/ZSI/F-12608, holotype, 97.0mm SL, India, Arunachal Pradesh: a—lateral | b—dorsal | c—ventral views. © L. Tamang.**

Image 2. ***Aborichthys barapensis*** **sp. nov., DNGC/F- 02, paratype, 91.0mm SL, India, Arunachal Pradesh, lateral view; showing caudal fin with dark grayish-brown bars and somewhat irregular medial bars.. © L. Tamang.**

vertical almost reaching to posterior margin of orbit. Mouth inferior and widely arched, 2.7–2.9* times wider than long. Lips soft, thick, fleshy & pleated, continuous all around with a deep furrow behind, upper lip broader than lower, with a small incision in the middle. Lower lip with two large roughly triangular pads or knobs

Table 1. Biometric data of *Aborichthys barapensis* sp. nov.

	Holotype	Paratype
Standard length (mm)	97	91
% Standard Length		
Head length	19.1	19.7
Head width	14.4	14.1
Dorsal head length	16.0	16.5
Head depth at nape	10.2	9.7
Body depth at dorsal-fin origin	13.4	12.7
Body width at dorsal-fin origin	12.2	11.6
Predorsal length	47.7	48.2
Pre-pectoral length	18.0	18.1
Pre-pelvic length	46.4	46.0
Pre-anal length	76.3	77.0
Pre-anus length	53.7	53.8
Pectoral-fin length	14.4	14.4
Pectoral-fin base length	5.2	4.4
Dorsal-fin length	13.5	15.4
Dorsal-fin base length	9.8	9.3
Pelvic-fin length	14.4	15.4
Pelvic-fin base length	3.6	3.4
Anal-fin length	13.6	13.3
Anal-fin base length	6.4	6.1
Caudal-fin length	17.0	17.7
Caudal peduncle length	18.0	17.5
Caudal peduncle depth	11.4	11.0
Distances from:		
Dorsal to caudal base	52.8	51.9
Pectoral to pelvic	30.4	28.9
Pectoral to anal	59.7	59.7
Pectoral to vent	40.7	38.7
Pelvic to anal	29.9	30.5
Pelvic to vent	10.4	9.9
Vent to anal	19.5	20.9
Vent to caudal-fin base	44.1	45.1
Anal to caudal base	25.8	24.5
Anal fin tip to caudal-fin base	11.3	10.8
% of Pelvic to anal fin origin		
Vent to anal distance	65.2	68.3
vent to pelvic distance	34.8	32.6
% of head length		
Head depth	44.7	53.5
Head width	71.5	75.7
Snout length	41.9	44.9
Eye diameter	11.2	12.4
Inter-orbital width	26.5	30.7
Mouth width	50.3	44.7
Mouth length	17.3	16.8
Inner rostral barbel length	17.8	21.8
Outer rostral barbel length	21.6	22.3
Maxillary barbel length	17.3	21.2
Ratio		
Caudal peduncle length/ caudal peduncle depth	1.6	1.6
Mouth width/mouth length	2.9	2.7

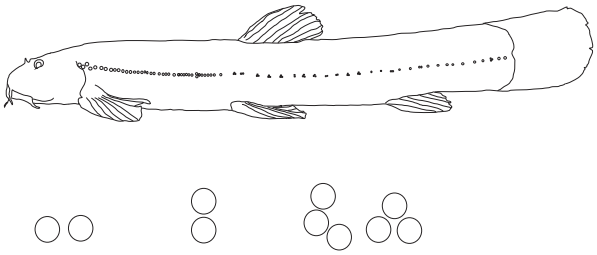

Figure 2. Sketch diagram of *Aborichthys barapensis* sp. nov., EBRC/ZSI/F-12608, holotype, 97.0mm SL, lateral view, showing three patterns of lateral line sensory pores (single, double, and triple).

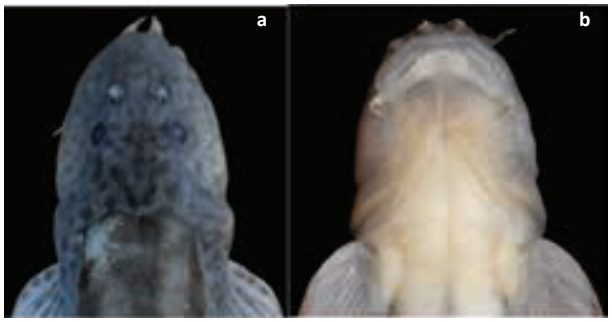

Image 3. *Aborichthys barapensis* sp. nov., EBRC/ZSI/F-12608, holotype, 97.0 mm SL: a—dorsum showing more graying dusky background and unclear spots, blotches or marks | b—ventral mottled with minute grayish-brown color. © L. Tamang.

separated by extremely narrow median interruption. Processus dentiformis prominent, situated in the middle on upper jaw, its anterior margin arched (Image 3b).

Dorsal fin with two simple and 7½ branched rays, situated at vertical almost in between pectoral-fin and anal-fin origins, at vertical slightly posterior to pelvic-fin origin, slightly closer to snout tip than to caudal-fin base, tip of last ray at vertical exceed to anal-fin tip, anterior margins slightly arched towards tip and distal arched, second or third branched ray the longest, length of dorsal and anal fins almost equal. Pectoral fin broadly leaf-shaped, tip obtusely rounded, with one simple, 11 branched rays, fourth or fifth branched ray the longest, anterior margin slightly convex, distal obtusely rounded and tip extending to middle of pectoral- and pelvic-fin origins. Ventral surface of first and second branched ray plain padded. Pelvic fin shape similar to pectoral fin, with 1 simple and 6* or 7 branched rays, surpassing considerably beyond vent, situated at vertical slightly anterior to dorsal-fin origin, inserted almost middle of pectoral- and anal-fin origins. A small prominent and fleshy axillary pelvic-fin lobe present. Anal-fin with 2*–3 simple and 5½ branched rays, anterior margin slightly convex and posterior straight. Caudal fin rounded and

deepest at posterior end, with first one unbranched ray, 17 branched rays and last one unbranched ray, distal margin moderately arched. Caudal peduncle length 1.6 times its depth. Caudal peduncle equal prepectoral length. Vent situated very closer to pelvic-fin origin (32.6–34.8 % of pelvic to anal-fin origin) than anal-fin origin (65.2–68.3 % of pelvic to anal-fin origin).

Body embedded with minute cycloid scales, more deeply embedded along abdominal mid region that extend up to posterior half of pectoral fin bases. No scales on dorsal and ventral surface of head. Lateral line complete, with 92*–95 pores, arranged in three patterns as single, double or triple (Figure 2). Pores aligned before pectoral fin origin slightly bulgy, prominent and closely set, causing distinct lateral line, pores beyond pectoral-fin origin very small, not bulgy, distantly placed and indistinct, causing poor lateral line which mostly consist of double and triple pores. Cephalic lateralis system comprises of 7+6+6* or 9+6+7 preoperculo-mandibular, 8* or 9 subopercular, 13*–14 suprapremaxillary, 10+12* or 9+12 infraorbital, 3+3* supraorbital, 5 temporal, 5 supratemporal, 11* or 10 nasal, 5* or 7 antero-nasal, and 2 pre-nasal (Figure 1).

Color in preservative

In live, body and head background dusky white with dark brown saddles, spots, irregular marks on body and head. Ventral and lateral region of head mottled with minute brown spots, over all seems brown patch. Cheek, isthmus, chest creamy and beyond up to level of anus dirty white. Dorsum of head darker than body in holotype (Image 3a). Three forms of oblique bars on flank– regular, bifurcate or fuse. Flanks with 24*–26 (6 pairs fused, 11*–13 regular, 1 bifurcate) dark brown oblique bars directed backwards, fused bars mostly appear on anterior part of body and one almost below middle of dorsal-fin base; regular and bifurcate bars mostly occur beyond dorsal fin; bars mostly broader than interspace. All fins background semi-transparent. Dorsal fin with 5*–6 rows of brown spots existing on each radial and one dark brown ocellus at its origin. Pectoral fin with 4–5 rows of brown spots, distinctiveness decreasing posteriorly. Pelvic fin with 3 rows of indistinct brown spots, and anal fin with few brown spots on distal half. Holotype: Caudal fin intense pinkish with five prominent black cross bars, first bar, broadest and moderately arched, situated at subdistal margin, second and third bars widely stretched W-shaped and complete, former slightly broader than later, fourth and fifth bar incomplete extending up to middle, almost of equal width, some part visible on lower edge after interruption, size of interspaces between bars decreasing towards caudal base, interspace between first and second bars broadest which appears to be caterpillar like (Image 1a). Paratype: Caudal fin light pinkish with five dark brown cross bars, first two outer bars distinct and moderately arched but proximal three bars indistinct, feebly arched and irregular without W-shaped pattern (Image 2).

In 70 % ethanol, body and head background grayish-dusky white. Bars, saddles, spots, irregular marks on body and head dark grayish-brown. All fins grayish and semi-transparent, proximal dorsal surface dusky. Caudal fin light pinkish (disappearing) with five dark grayish-brown cross bars in holotype, whereas pinkish color disappeared with five grayish-brown cross bars in paratype. Proximal region of caudal fin more grayish in paratype than holotype.

Remarks: Live holotype exhibits prominent black cross bars on caudal fin with deep pinkish background, whereas dark brown, light pink, and irregular proximal bars in paratype (may be former male and later female).

Comparison. *Aborichthys barapensis* is easily distinguished from all its congeners in lacking a black ocellus on the upper end of the basicaudal bar (vs. present). It can be further differentiated from *A. kempi*, *A. tikaderi*, *A. elongatus*, *A. garoensis*, *A. iphipaniensis*, *A. kailashi*, *A. waikhomi* and *A. pangensis* by the presence of five cross bars on caudal fin (vs. usually two concentric bars in *A. kempi*, *A. tikaderi*, *A. elongatus*, *A. garoensis*, *A. iphipaniensis* and *A. kailashi*; cluster of spots in *A. pangensis*; irregular black blotches in *A. waikhomi*). Moreover, distal margin of the caudal fin moderately rounded (vs. almost circularly rounded in *A. elongatus* and *A. tikaderi*; U-shaped in *A. garoensis*; truncate in *A. waikhomi* and *A. pangensis*; and obliquely rounded in *A. kempi, A. iphipaniensis*, and *A. kailashi* (compare Image 1a with Kosygin 2012; Figure 4a,b,c,e,f for *A. elongatus*, *A. tikaderi*, *A. garoensis*, *A. waikhomi* and *A. kempi*; Kosygin et al., 2019; Figure 1b for *A. iphipaniensis*; Shangningam et al., 2019; Figure 1 for *A. kailashi*). Further, from *A. boutanensis*, *A. kempi, A. elongatus, A. garoensis, A. tikaderi, A. waikhomi, A. iphipaniensis, A. kailashi*, and *A. pangensis* in having very low and short (vs. prominent) dorsal and ventral adipose crests, but absent in *A. waikhomi*.

The genus *Aborichthys* exhibits three different positions of vent (Hora 1925): (1) closer to snout tip than to caudal-fin base (Kosygin et al. 2019: *A. garoensis, A. tikaderi, A. iphipaniensis*), (2) closer to caudal-fin base than to tip of snout (Kosygin et al. 2019; Chaudhuri 1913; Shangningam et al. 2019: *A. boutanensis, A. elongatus, A.* waikhomi; *A. kempi, A. kailashi*, and *A.*

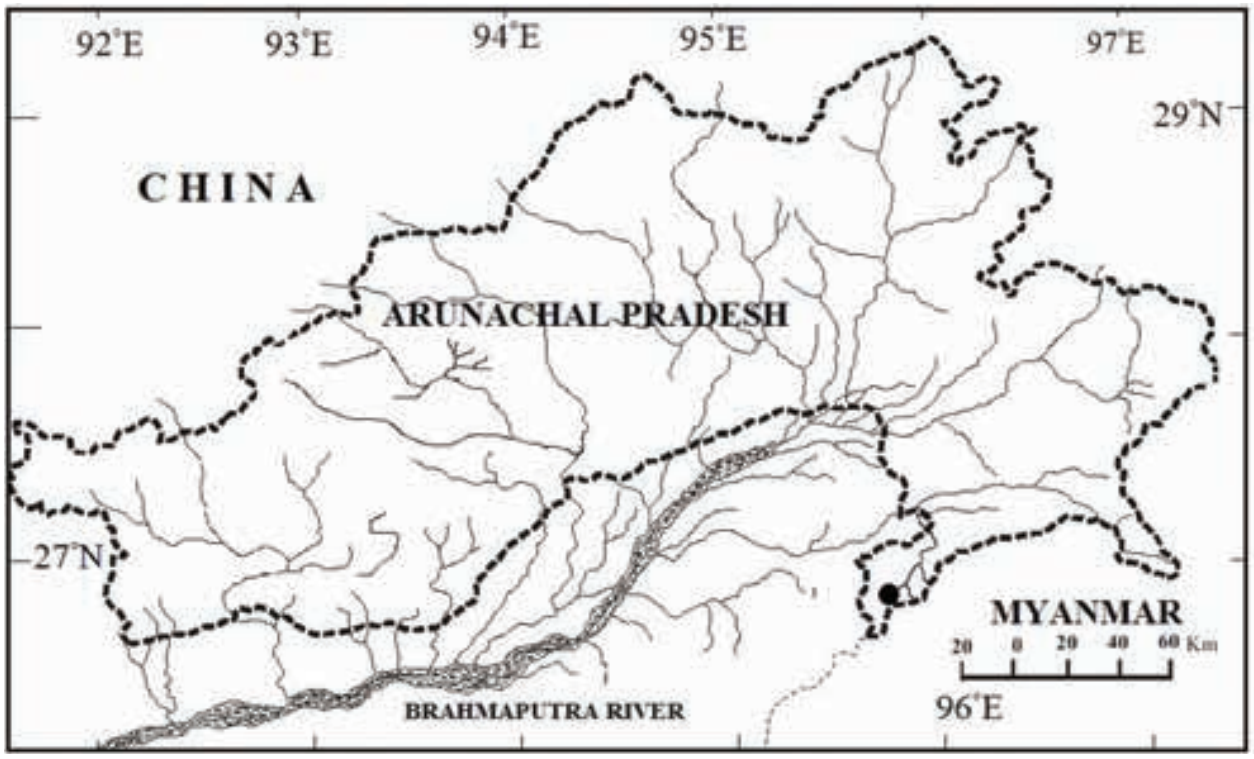

Figure 3. Map of Arunachal Pradesh, showing Barap Stream (filled circle), the type locality of *Aborichthys barapensis* sp. nov., India.

pangensis), (3) almost in the middle between snout tip and caudal-fin base, which is used as generic character to differentiate other nemacheilid genera and among species as well (Kottelat 1990). As per the recent study (Kosygin et al. 2019), the third condition is not fulfilled to any *Aborichthys* species. *Aborichthys barapensis* belongs to the above second condition and hence, can be further distinguished from *A garoensis, A. tikaderi, A. iphipaniensis* by having the vent closer to caudal-fin base than to snout tip (vs. closer to snout tip than to caudal-fin base); furthermore, it can be differentiated from *A. garoensis*, *A. iphipaniensis, A. kailashi,* and *A. pangensis* by having a fewer oblique bars on flank (24–26 vs. 28–29 in *A. garoensis*; 33–35 in *A. iphipaniensis*; 28–36 in *A. kailashi*, and 34–38 in *A. pangensis*) and from *A. elongatus*, *A. kempi*, *A. tidakeri*, and *A. waikhomi* by having more oblique bars on flank (24–26 vs. 17–22 in *A. elongatus*; 18–19 in *A kempi*; 16–20 in *A. tikaderi*; and 12–16 in *A. waikhomi*). It is further distinguished from *A. iphipaniensis*, *A. garoensis*, *A. kempi*, and *A. waikhomi* in having oblique bars mostly broader than interspace (vs. narrower) along body.

Aborichthys barapensis can be further differentiated from *A. boutanensis* in having shorter pre-anus length (53.7–53.8 % SL vs. 70.9), longer predorsal length (47.7–48.2 % SL vs. 45.7), shallow caudal peduncle (11.0–11.4 % SL vs. 12.3) and shorter caudal peduncle (17.5–18.0 % SL vs. 19) and from *A. iphipaniensis* by having a higher body (12.7–13.4 % SL vs. 8.9–9.9); a longer predorsal (47.7–48.2 % SL vs. 42.4–44.4), prepelvic (46.0–46.4 % SL vs. 39.4–42.0), and pelvic fin (14.4–15.4 % SL vs. 10.3–12.7); and a shorter distance between vent and

Image 4. Type locality (Barap Stream) of *Aborichthys barapensis* sp. nov., near Lazu Village, Tirap District, Arunachal Pradesh.

anal-fin origin (19.5–20.9 % SL vs. 24.1–27.5).

Distribution and habitat

The new species were collected from the Barap Stream in shallow water (ca 10–30 cm depth) near Lazu Village in the southeastern part of Arunachal Pradesh (Figure 3). The substrate comprises mostly medium-sized boulders, and mixture of pebbles, cobbles, small stones and large boulders somewhere of light to dark grayish colors (Image 4). The water in the stream was cool, clear and moderately flowing due to considerable decrease in water volume in dry season. Riparian vegetation comprises grasses, shrubs and small to medium sized trees along the banks and larger trees uphill. The Barap Stream originates from the hills and deep forest near Raho Village, about 10 km from Lazu Village towards south and flows downward and forms Tirap River in the lower reach, further moves towards north and north-east through Changlang Town and meet with Noa-dihing River, which eventually confluences with Brahmaputra River in the state of Assam towards the west. Other associated fish collected belongs to genus *Schizothorax richardsonii, Garra* sp., *Amblyceps* sp., *Psilorhynchus balitora, Devario aequipinnatus*, and *Exostoma labiatum*.

Etymology

The specific name is derived from the name of the river Barap from where the present new species was obtained.

DISCUSSION

The description of the new species based on two specimens, indeed is challenging in the field of taxonomy. The present new species, however, is set forth for description is based chiefly on an important generic character of *Aborichthys*, i.e., the absence of a black ocellus on the upper end of the basicaudal bar, whereas it's present in all congeners. Apart from this, following secondary additional significant external characters also support in being distinct from its congeners, i.e., the presence of very low dorsal and ventral adipose crests on caudal peduncle except *A. waikhomi* and considerably to some extent, head and body in preservative being more grayish dusky white causing respective bars, saddles, spots or irregular marks on the body and head indistinct, whereas usually exhibit creamy to yellowish light background that gives distinctiveness in rest of the congeners, the caudal fin moderately arched with a slight oblique distal margin. Moreover, from the geographically point of view, the type locality of the new species is situated southeastern most part of the state, bordering Myanmar, where no any species of *Aborichthys* have so far been reported. As far as cephalic lateralis system is concerned, the presence of nasal, antero-nasal, pre-nasal, triple rows of preoperculo-mandibular, and three patterns of lateral line sensory pores (single, double and triple) deserve an additional information, may be used as an essential comparative characters in future course of study? Besides, the present study also exposed and well-defined the reason hidden behind the occurrence of distinct or indistinct lateral line. Close observation showed that little bit elevated and closely set sensory pores reflects distinct lateral line that can be seen by naked eye, restricted just before the pelvic-fin origin, whereas small and distantly placed pores fail to show lateral line up to the base of caudal fin.

A perusal of literature revealed that there are two more names *Aborichthys cataracta* and *A. verticauda* published in a predatory journal (Raghavan et al. 2014) which is against the policy of JoTT (Raghavan et al. 2015). Hence, these two species have not been taken into consideration.

Comparative material

Aborichthus waikhomi, V/APRC/ZSI/P-519, 05.xi.2009, paratypes, 3 specimens, 61.0–66.5 mm SL, a stream of Noa-Dihing River near Hornbill camp, Namdapha, Arunachal Pradesh, India, Coll. J.K. De & party.

A. iphipaniensis, ZSI/V/APRC/P-1659, 4.iv.2016, paratypes, 3 specimens, 107.5–120.8 mm SL, Iphipani River at Roing, Lower Dibang Valley, Brahmaputra River basin, Arunachal Pradesh, India, coll. S. Devi and party.

Data for *A. boutanensis*, *A. kempi*, *A. elongatus, A. tikaderi, A. garoensis*; *A. kailashi* and *A. pangensis* accessed from Chaudhuri 1913; Shangningam et al. 2019; Thoni & Hart 2015.

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COMMUNICATION

A study on the community structure of damselflies (Insecta: Odonata: Zygoptera) in Paschim Medinipur, West Bengal, India

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Abstract: For gauging suitability of zygopteran odonates as bioindicators of ecosystems, an attempt was made to record the seasonal diversity of damselflies from seven different types of habitats in Paschim Medinipur District, West Bengal covering 14 land use sites. The study revealed existence of 19 species of damselflies belonging to 10 genera under two families. While the riparian zone had maximum number of species (15), paddy field had the lowest number (six). *Ceriagrion coromandelianum* and *Agriocnemis pygmaea* were the most common species. *C. coromandelianum* was eudominant in grassland and wetland-forest interface, whereas *A. pygmaea* was eudominant in fish pond and paddy field. Six species, viz., *Paracercion calamorum*, *P. malayanum*, *Pseudagrion australasiae*, *P. decorum, P. spencei*, *and P. microcephalum* were confined only to the riparian zone. Maximum abundance of damselflies was found in the riparian zone and minimum in the paddy field. Damselflies exhibited a distinct peak in March–April and a lesser peak in September–October. Most of the land use patterns exhibited similar zygopteran faunal composition. Species diversity index was moderate (1.4–2.5) and evenness index was on the higher side (0.76–0.94). Dominance Index ranged from 26.2 to 64.6. Riparian zone appeared to be the least stressed and most equitable habitat with highest diversity and evenness index and lowest dominance index. Paddy field seemed to be the harshest habitat for damselflies with least diversity and highest dominance index. The present study suggests that community analysis of damselflies can be quite useful in the assessment of the quality of any ecosystem.

Keywords: Bioindicator, damselfly, dominance index, evenness index, land use type, species diversity index, Zygoptera.

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Author contributions: PKJ conducted field work with regular data collection, identification and documentation along with interpretation of results and preparation of initial manuscript. PHM has designed and supervised the study with contribution in editing and reviewing the draft article and maintaining communications. TB has provided inputs in data analysis and interpretation, revision and write-up of final manuscript.

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INTRODUCTION

Sensitivity of damselflies to structural habitat features and their amphibious habit makes them well suited as bioindicators of environmental changes (Subramanian et al. 2008; Dolný et al. 2011). In general, odonates have been popular for monitoring health of wetlands all over the world (Chovanec & Waringer 2001). The species assemblages of damselflies are influenced by the aquatic and terrestrial vegetation which act as one of the main cues for their habitat choice. Although considerable work has been done on the ecology and diversity of odonates in many parts of India, some of the latest ones are those of Baba et al. (2019), D'Souza & Pai (2019), Payra et al. (2020), Bedjanič et al. (2020), and Pavithran et al. (2020).

In West Bengal, Odonata fauna has been explored in recent years by Payra & Tiple (2019) & Pahari et al. (2019) from Purba Medinipur and Nayak (2020) from Asansol–Durgapur industrial area. Despite efforts of Jana et al. (2009), large parts of Paschim Medinipur have remained unexplored with respect to odonate distribution and ecology. In the aforementioned context, the present study was undertaken across different habitat structures and land use patterns comprising aquatic and semi–aquatic water bodies of Paschim Medinipur District.

METHODS

Study area

The present study was carried out in five blocks of Paschim Medinipur District of West Bengal, India namely Pingla, Debra, Kharagpur I, Kharagpur II and Midnapore, predominantly encompassing freshwater lentic wetlands (Figure 1). On the basis of the habitat heterogeneity, seven land use types, viz., fish pond (FP), eutrophic pond (EP), unmanaged wetland (UW), grassland (GL), paddy field (PF), wetland-forest interface (WFI), and riparian zone (RZ) were selected (Image 1a–g). The fish pond was a semi-natural water body used only for commercial fish culture and with little littoral and floating macrophytes. The man-made eutrophic pond, having high nutrient content, was severely infested with *Pistia* sp. (90 %), with smaller proportions of *Alternanthera philoxeroides* (8 %) and other hydrophytes (2 %). Unmanaged wetland was a natural water body with profuse macrophytes of varieties. The macrophytes were inventoried with reference to Mallick & Chakraborty (2014). Grassland included open fallow lands having stretches of herbaceous plants dominated by grasses. Paddy fields were lands under paddy cultivation. Wetland-forest interface were the confluence of homestead vegetation and water bodies. Riparian zone comprised of riverbank along Kangsabati River.

Sampling

Field sampling of adult zygopterans was done from March 2018 to February 2019. The sampling and quantitative measurements of adult damselfly species were carried out at each study site between 0800 h and 1400 h using line transect method. Transect routes, distances walked, and durations were kept constant across study sites throughout the survey. All sites were surveyed once per month preferably under reasonable weather conditions, barring a few instances. The prominent features of the study sites were also noted on the spot. Adult damselfly species were identified and photographed in the field; doubtful specimens were captured using an aerial insect net. Later they were identified by examining the morphological characteristics through a hand lens and were released after recording. For identification purpose, few damselflies were sacrificed by gently pressing their thorax and kept dry in paper envelope or in 70 % ethanol and were brought to the laboratory. The observed and collected species were identified to the lowest possible rank using taxonomic literature and field identification keys provided by Subramanian (2009), Mitra & Babu (2010), and by photographic guides from 'Odonata of India' website (Anonymous 2020). Updated species names were taken following the Subramanian & Babu (2017).

Data analysis

Important community parameters like abundance, relative abundance, Shannon–Wiener diversity index (H′) (Shannon & Wiener 1963), evenness index of Pielou (EI) (Pielou 1975), McNaughton & Wolf's dominance index (DI) (McNaughton & Wolf 1970), and Sørensen's similarity index (Sørensen 1948) were calculated using MS Excel.

RESULTS

During the course of study, 19 zygopteran species belonging to 10 genera under two families were recorded from the study sites. The family Coenagrionidae contained 17 species and family Platycnemididae contained two species.

Species richness exhibited spatial and temporal changes (Table 1). RZ had maximum numbers of species

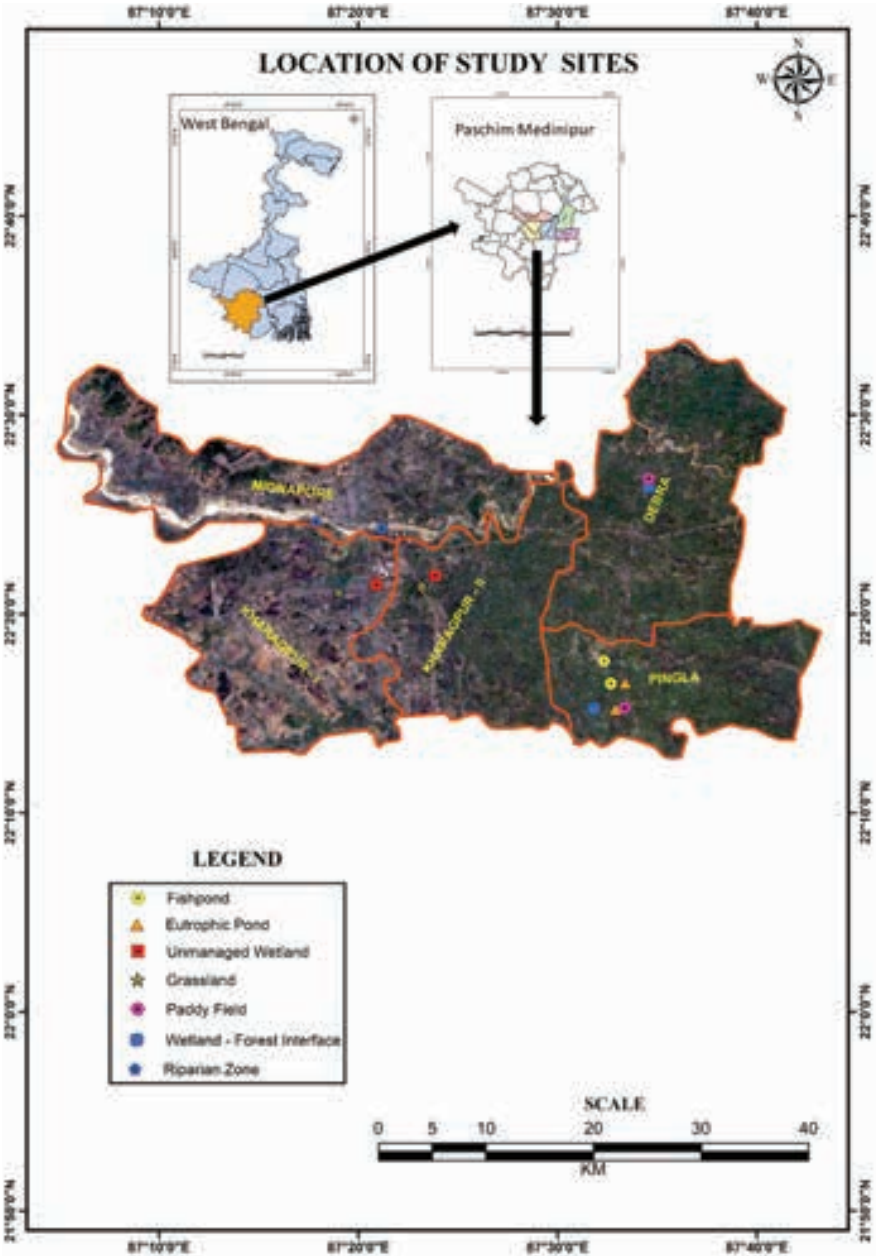

Figure 1. Map of Paschim Medinipur District within the state of West Bengal, showing locations and land use types of all study sites.

(15). This was followed by UW (13), FP (12), GL (10), EP (8), WFI (7) and PF (6).

Maximum number of individuals was recorded at RZ and minimum at PF. Like species richness, number of individuals also varied spatially and temporally (Table 1; Figure 2). Damselfly exhibited a more or less bimodal pattern of population fluctuation with two peaks, first one in the pre-monsoon period (March–April) and the second one in the post-monsoon period (September–October) which was not quite distinct in the WFI (Figure 2). From paddy fields no damselfly species were recorded in the month of June. WFI has highest abundance only in pre-monsoon period and there was little increase in number of individuals in post-monsoon period as compared to other land use types.

Dominance status of each species in a particular habitat was ascertained on the basis of its relative abundance according to scale of Engelmann (1973). Table 1 reveals that *Agriocnemis pygmaea* was eudominant species in FP and PF and dominant in remaining five habitats. Likewise, *Ceriagrion coromandelianum* was eudominant in GL and WFI and dominant species in the remaining habitats. No species was eudominant in EP, UW, and RZ. Other dominant species were *Ceriagrion cerinorubellum* & *Copera marginipes* in EP and WFI, *Agriocnemis lacteola* & *Ischnura rubilio* in PF, *Ischnura*

Table 1. Species richness (S), number (N), relative abundance (RA in %), and dominance status (DS) of zygopteran species in different land use types.
[RA <1= subrecedent (SR); 1–3.1= recedent (R); 3.2–10= subdominant (SD); 10.1–31.6= dominant (D); >31.7= eudominant (ED)] (Engelmann 1973).

	Landuse Types →	FP			EP			UW			GL			PF			WFI			RZ		
	Scientific Names ↓	N	RA	DS	N	RA	DS	N	RA	DS	N	RA	DS	N	RA	DS	N	RA	DS	N	RA	DS
Family Coenagrionidae																						
1	*Agriocnemis kalinga* Nair & Subramanian, 2015	1	0.2	SR	-	-	-	32	5.4	SD	4	1.2	R			-	-	-	-	62	6.1	SD
2	*Agriocnemis lacteola* Selys, 1877	-	-	-	-	-	-	28	4.7	SD	33	9.8	SD	23	11.8	D	-	-	-	-	-	-
3	*Agriocnemis pygmaea* (Rambur, 1842)	200	34.0	ED	98	21.4	D	159	26.9	D	98	29.2	D	75	38.5	ED	43	15.9	D	123	12.1	D
4	*Amphiallagma parvum* (Selys, 1876)	25	4.2	SD	-	-	-	39	6.6	SD	-	-	-	-	-	-	-	-	-	99	9.7	SD
5	*Ceriagrion cerinorubellum* (Brauer, 1865)	16	2.7	R	77	16.8	D	48	8.1	SD	24	7.1	SD	4	2.1	R	32	11.8	D	34	3.3	SD
6	*Ceriagrion coromandelianum* (Fabricius, 1798)	68	11.5	D	102	22.3	D	67	11.3	D	115	34.2	ED	38	19.5	D	105	38.7	ED	124	12.2	D
7	*Ischnura rubilio* Selys, 1876	39	6.6	SD	6	1.3	R	13	2.2	R	15	4.5	SD	51	26.2	D	-	-	-	38	3.7	SD
8	*Ischnura senegalensis* (Rambur, 1842)	77	13.1	D	-	-	-	42	7.1	SD	13	3.9	SD	4	2.1	R	-	-	-	123	12.1	D
9	*Mortonagrion aborense* (Laidlaw, 1914)	22	3.7	SD	26	5.7	SD	30	5.1	SD	-	-	-	-	-	-	33	12.2	D	-	-	-
10	*Onychargia atrocyana* (Selys, 1865)	4	0.7	SR	45	9.8	SD	36	6.1	SD	8	2.4	R	-	-	-	12	4.4	SD	-	-	-
11	*Paracercion calamorum* (Ris, 1916)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	2.6	R
12	*Paracercion malayanum* (Selys, 1876)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	4.2	SD
13	*Pseudagrion australasiae* Selys, 1876	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	2.6	R
14	*Pseudagrion decorum* (Rambur, 1842)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	142	14.0	D
15	*Pseudagrion microcephalum* (Rambur, 1842)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	51	5.0	SD
16	*Pseudagrion rubriceps* Selys, 1876	46	7.8	SD	-	-	-	16	2.7	R	-	-	-	-	-	-	-	-	-	64	6.3	SD
17	*Pseudagrion spencei* Fraser, 1922			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	2.7	R
Family Platycnemididae																						
18	*Copera marginipes* (Rambur, 1842)	39	6.6	SD	72	15.7	D	52	8.8	SD	13	3.9	SD	-	-	-	41	15.1	D	-	-	-
19	*Pseudocopera ciliata* (Selys, 1863)	52	8.8	SD	32	7.0	SD	29	4.9	SD	13	3.9	SD	-	-	-	5	1.8	R	35	3.4	SD
	Total number of Species (S)	**12**			**8**			**13**			**10**			**6**			**7**			**15**		
	Total number of Individuals (N)	**589**			**458**			**591**			**336**			**195**			**271**			**1017**		

Table 2. Sørensen's index of similarity between land use types.

	EP	UW	GL	PF	WFI	RZ
FP	0.80	0.96	0.82	0.56	0.74	0.67
EP		0.76	0.78	0.57	0.93	0.43
UW			0.78	0.63	0.70	0.57
GL				0.75	0.71	0.56
PF					0.46	0.48
WFI						0.36

[0.5–0.6= slightly similar; 0.6–0.7= moderately similar; >0.7= strongly similar; 0.5–0.4= slightly dissimilar; 0.4–0.3= moderately dissimilar; <0.3= strongly dissimilar.]

Table 3. Shannon-Wiener diversity index, evenness index, and dominance index of different land use types.

Land use types	S-W Diversity index (H')	Evenness index (EI)	Dominance index (DI)
FP	2.1	0.83	47.0
EP	1.9	0.91	43.7
UW	2.3	0.91	38.2
GL	1.7	0.76	63.4
PF	1.4	0.81	64.6
WFI	1.7	0.86	54.6
RZ	2.5	0.94	26.2

senegalensis & *Pseudagrion decorum* in RZ, and *Mortonagrion aborense* in WFI. Rest of the species were either subdominant or recedent. Three species, viz., *Paracercion calamorum, Pseudagrion australasiae*, and *Pseudagrion spencei* were recedent in the riparian zone. In FP, two species (*Agriocnemis kalinga* and *Onychargia atrocyana*) were subrecedent.

Interestingly, no representative of family Platycnemididae was found in PF during the entire period of investigation. Turning to the analysis of species composition based on Sorensen's index (Table 2), it is seen that WFI was moderately dissimilar in zygopteran faunal composition with RZ and slightly dissimilar with PF. Likewise, RZ was slightly dissimilar with PF and EP. All other habitats were similar in species composition. Maximum similarity was seen between FP and UW.

Analysis of diversity and evenness indices (Table 3) revealed that species diversity indices were relatively low ranging from 1.4 in the PF to 2.5 in the RZ. Evenness index, on the contrary, was on the higher side ranging between 0.76 in the GL to 0.94 in the RZ. Simultaneously, dominance Index ranged from 26.2 (RZ) to 64.6 (PF).

DISCUSSION

Spatial heterogeneity is often regarded as a key factor that shapes diversity (Tews et al. 2004). Structurally complex habitats provide more niches and diverse ways of exploiting the environmental resources thereby increasing species diversity (Bazzaz 1975). In the present study, 19 species of Zygoptera were recorded which is comparable to the findings of Pahari et al. (2019) who found 20 species from Purba Medinipur District. Lower species richness recorded by them in all probability is because of urbanization. Most of the study sites in the present investigation exhibited similar species composition which might be attributed to the spatial proximity of sites but differences in land use types made some habitats dissimilar in species composition.

Increased richness and abundance of damselflies during pre-monsoon period, as observed in the present study, is in accordance with the findings of Corbet (2004) and Hassall & Thompson (2008), who observed higher richness and abundance during pre-monsoon period which they assigned to increased temperature and precipitation. Documentation of zygopteran diversity is important for the assessment of the health of agroecosystem. The odonate diversity in the present study was reported to be lower in agricultural landscapes than in other ecosystems, which corroborates with the findings of Kulkarni & Subramanian (2013) and it has been suggested that the lower diversity was due to the water quality, insecticide usage and vegetation structure in the paddy fields which significantly affects the zygopteran community (Baba et al. 2019; Giuliano & Bogliani 2019).

Ceriagrion coromandelianum and *Agriocnemis pygmaea* were the most common species encountered during the present study being eudominant and dominant species, respectively, wherever these were distributed. Relatively low species diversity index is suggestive of a relatively harsh, stressed and disturbed habitat. According to Wilhm & Dorris (1968) general diversity index ranging 1–3, suggests a moderate disturbance or stress operating in the habitat. Of the seven land use types, the riparian zone appears to be relatively less stressed whereas paddy field appears to be the most stressed. These human-altered ecosystems can be essential in serving as alternative habitats for biodiversity, especially water reliant species such as odonates. Species diversity and evenness indices in the present study are comparable with those of a study by Pahari et al. (2019) in Purba Medinipur District. Higher evenness indices (>0.8) in majority of the habitat types

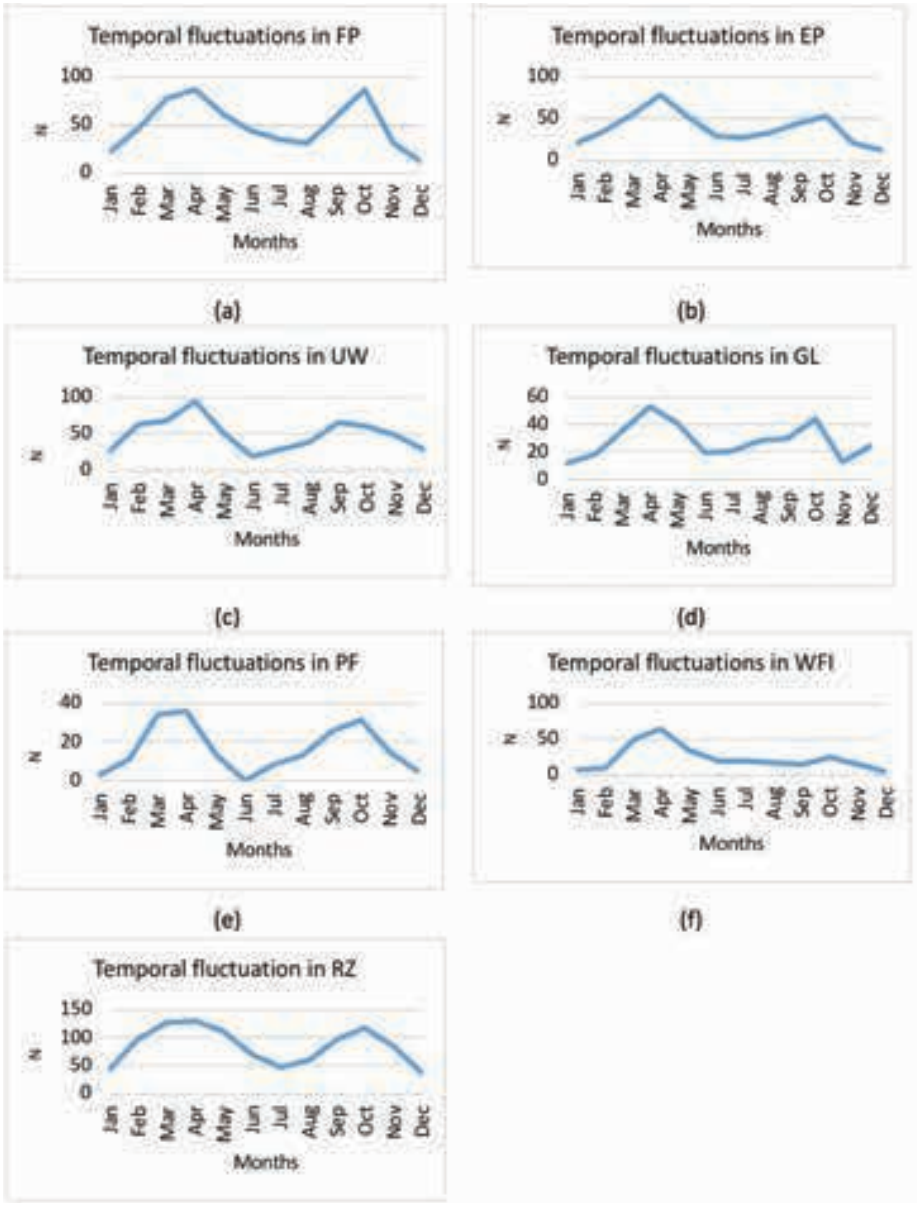

Figure 2. Temporal fluctuation in Number of Individuals (N) of damselflies during 2018–2019 across land use types. [FP= fish pond, EP= eutrophic pond, UW= unmanaged wetland, GL= grassland, PF= paddy field, WFI= wetland-forest interface, RZ= riparian zone].

indicate a structural heterogeneity of the habitats. Grassland with the least evenness index appears to be the most homogeneous habitat.

Findings pertaining to the dominance index also substantiate the relation between species diversity and habitat structure and quality. McNaughton & Wolf (1970) asserted that the dominance index can be correlated with the harshness of the environment, which increases with the increase in harshness and decreases with the equitability of the habitat. Karr (1971) and Ghosh & Bhattacharya (2018) though found that dominance index for avifauna declined with vegetational development. Pahari et al. (2019) opined that dominance index of odonates is an indicator of the quality of environment. Harsh environment favours dominance of one or two species making them eudominant or dominant by eliminating some other species. In the present study, dominance index was high in paddy field and grassland which are structurally simple with little vegetational diversity subjected to greater anthropogenic interferences, experience more fluctuation of climatic and edaphic factors and as such are less equitable and harsh as compared to other habitats. On the contrary, riparian zone and unmanaged

(a) FP

(b) EP

(c) UW

(d) GL

(e) PF

(f) WFI

(g) RZ

Image 1. Study sites in selected blocks: a—fish pond in Pingla | b—eutrophic pond in Pingla | c—unmanaged wetland in Kharagpur II | d—grassland in Kharagpur I | e—paddy field in Debra | f—wetland–forest interface in Pingla | g—riparian zone in Midnapore. © Pathik Kumar Jana. EP—eutrophic pond | FP—fish pond | GL—grassland | PF—paddy field | RZ—riparian zone | UW—unmanaged wetland | WFI—wetland–forest interface.

wetland had low dominance index and hence may offer better and equitable habitat resulting into relatively high zygopteran species diversity as compared to other land use types. It may thus be concluded that the damselflies have potentiality to be used as good indicators of the condition and health of land use types and habitat quality.

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OPEN ACCESS

COMMUNICATION

New distribution and range extension records of geometrid moths (Lepidoptera: Geometridae) from two western Himalayan protected areas

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Abstract: This article presents new distribution and range extension records (including new records from the state of Uttarakhand) of 12 species of the Geometridae family along with their taxonomic records. The records are based on field collections, where sampling was done along elevation and vegetation gradients in the buffer zones of Nanda Devi Biosphere Reserve and Kedarnath Wildlife Sanctuary, two prominent protected areas in the western Himalayan Indian state of Uttarakhand. DNA barcoding was performed for some of the species for confirmation of identification in addition to the morphological identifications. Voucher specimens are deposited in a public repository for future reference.

Keywords: DNA barcoding, Ennominae, Kedarnath Wildlife Sanctuary, Larentiinae, Nanda Devi Biosphere Reserve, Uttarakhand.

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Competing interests: The authors declare no competing interests.

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Author contributions: PD secured funding, conceived the study and did the data collection; AH verified the taxonomic details; PD and AH wrote the manuscript.

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INTRODUCTION

Geometridae are the second-largest family of moths, globally distributed, known to include approximately 24,000 species worldwide (Scoble & Hausmann 2007; VanNieukerken et al. 2011), whereas 2,041 species are recorded from India (Kirti et al. 2019). Most species are slenderly built, generally with weak flying ability, and nocturnal or crepuscular. At rest, the fasciae of the wing pattern are continuous. Geometrids are recognised by the presence of paired tympanal organ at the base of the abdomen in adults and the reduced prolegs in the larvae (Minet & Scoble 1999). This group has also been the subject of a number of recent large-scale taxonomic and phylogenetic works (e.g., Sihvonen & Siljander 2005; Sihvonen et al. 2011, 2020; Brehm et al. 2019; Murillo-Ramos et al. 2019). Although the taxonomy of this family is well established for the temperate regions, tropical areas still need large-scale revisions.

Geometrid moths have been established as a model group for biodiversity studies, community analyses, and ecological research in temperate and tropical regions (Axmacher et al. 2004, 2009; Brehm et al. 2013, 2018; Beck et al. 2017). They are sensitive to climate change (Cheng et al. 2018) and environmental conditions, making them an ideal indicator group to monitor forest recovery and habitat disturbance (New 2004; Beck et al. 2017).

The distribution records of this crucial group of moths with vast diversity, however, still remain scattered from India. The comprehensive work on moths of different regions of the biodiverse rough terrains of western Himalaya, a Biodiversity hotspot within the Indian territory, was mostly carried out by Hampson (1892, 1894, 1895, 1896) in his 'Fauna of British India' series and Cotes & Swinhoe (1887) in 'A Catalogue of Moths of India'. Some studies later on focussed on the diversity and taxonomy of geometrid moths from this region, which include: Pajni & Walia (1984a,b), Walia & Pajni (1987), Rose (1986), Walia (1988, 2005), Smetacek (2004), Walia & Anju (2005), Kirti et al. (2007, 2008a,b, 2009, 2011, 2014), and Stüning & Walia (2009).

From the western Himalayan state of Uttarakhand, where our study was conducted, some prominent work on moth diversity include: Arora (1997), Smetacek (1994, 2008), Sanyal et al. (2011, 2013, 2017), Dey et al. (2015, 2017), Sanyal (2015), Sondhi & Sondhi (2016) and Dey (2019). Sanyal et al. (2011, 2013) and Dey et al. (2015, 2017) looked into the diversity and distribution of moth assemblages. Dey et al. (2019) present a DNA barcode reference library of geometrid species from western Himalaya. Recently, Chandra et al. (2019) included moth diversity in two Protected Areas from Uttarakhand. There is a lot of area still to be studied in this mountainous state to understand the diversity and the underlying patterns in a more comprehensive way.

Our current study was conducted in two western Himalayan protected areas: a) Nanda Devi National Park area which is a part of the Nanda Devi Biosphere Reserve (NDBR). It covers an area of 6,407.03km² (core area: 712.12km², buffer zone: 5148.57km², and transition zone: 546.34km²), with an altitudinal range of 1,800m–7,816m; and b) The Kedarnath Wildlife Sanctuary (KWS) (30.416–30.683 N, 78.916–79.366 E). The altitude ranges 1,160–7,068 m covering an area of 975 km². Both these protected areas are located in the Chamoli-Rudraprayag District in the state of Uttarakhand and are the prominent protected areas in the western Himalaya. The habitats range from mixed oak forests to the lush alpine meadows (Image 1). The combination of human pressure, pristine forest areas and a large altitudinal range make them ideal sites for exploring trends in moth diversity.

Here we present new geographic distribution and range extension records of 12 geometrid species from the state of Uttarakhand which will add to the distribution data of this family from a threatened and fragmented landscape of the western Himalaya.

METHODS

Sampling methodology

Specimens were collected from the buffer regions of two protected areas in the western Himalayan state of Uttarakhand, Nanda Devi Biosphere Reserve (NDBR) and Kedarnath Wildlife Sanctuary (KWS) (Image 2). The study areas were stratified on the basis of elevation and vegetation types to explore the moth diversity along these gradients. Sampling was done at every 200 m along the elevation from 1,500 m to 3,500 m (details of the collection sites in Table 1). Two light-traps with 12W solar lamps were operated for the first 3–4 hours from dusk as this is the time of maximum activity of most geometrid species. Late night sampling was not possible due to logistic constraints. In KWS, we used lepiLED (Brehm 2017) to set up the light-trap.

DNA barcoding

Specimens of some species were DNA barcoded (COI 5' gene aiming at recovering the 658 bp barcode fragment). To do this, one dry leg was removed from

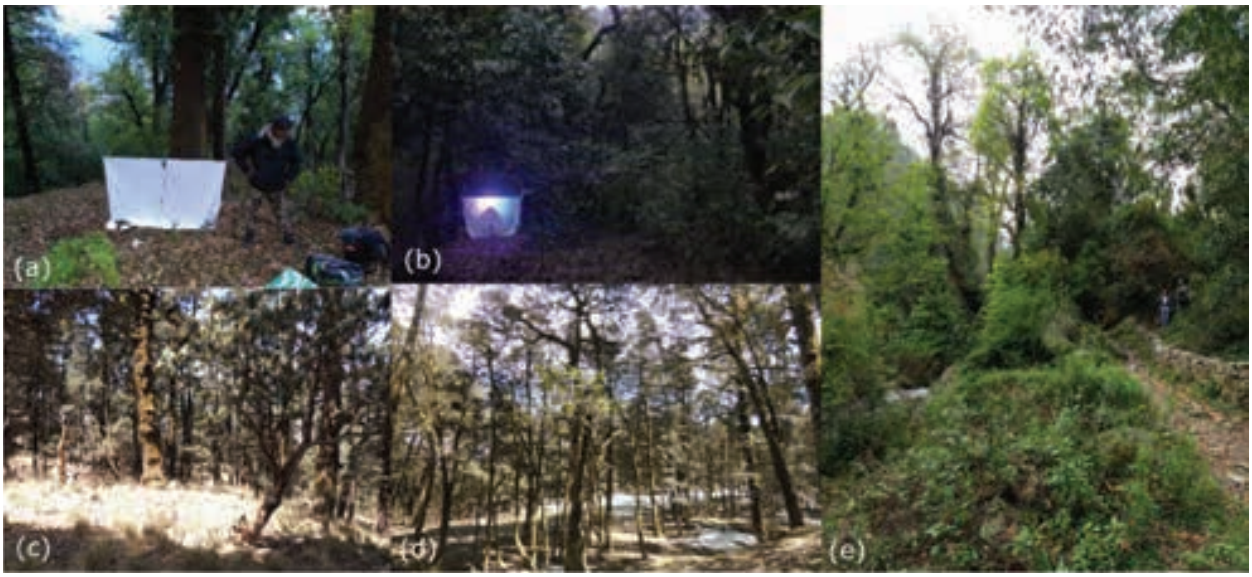

Image 1. Some of forest types where sampling was done within the two protected areas: a—Oak-Maple forest | b—Moru Oak *Quercus floribunda* forest | c—Alpine Rhododendron Forest | d—Kharsu Oak *Quercus semecarpifolia* forest | e—Western mix coniferous forest. © Pritha Dey.

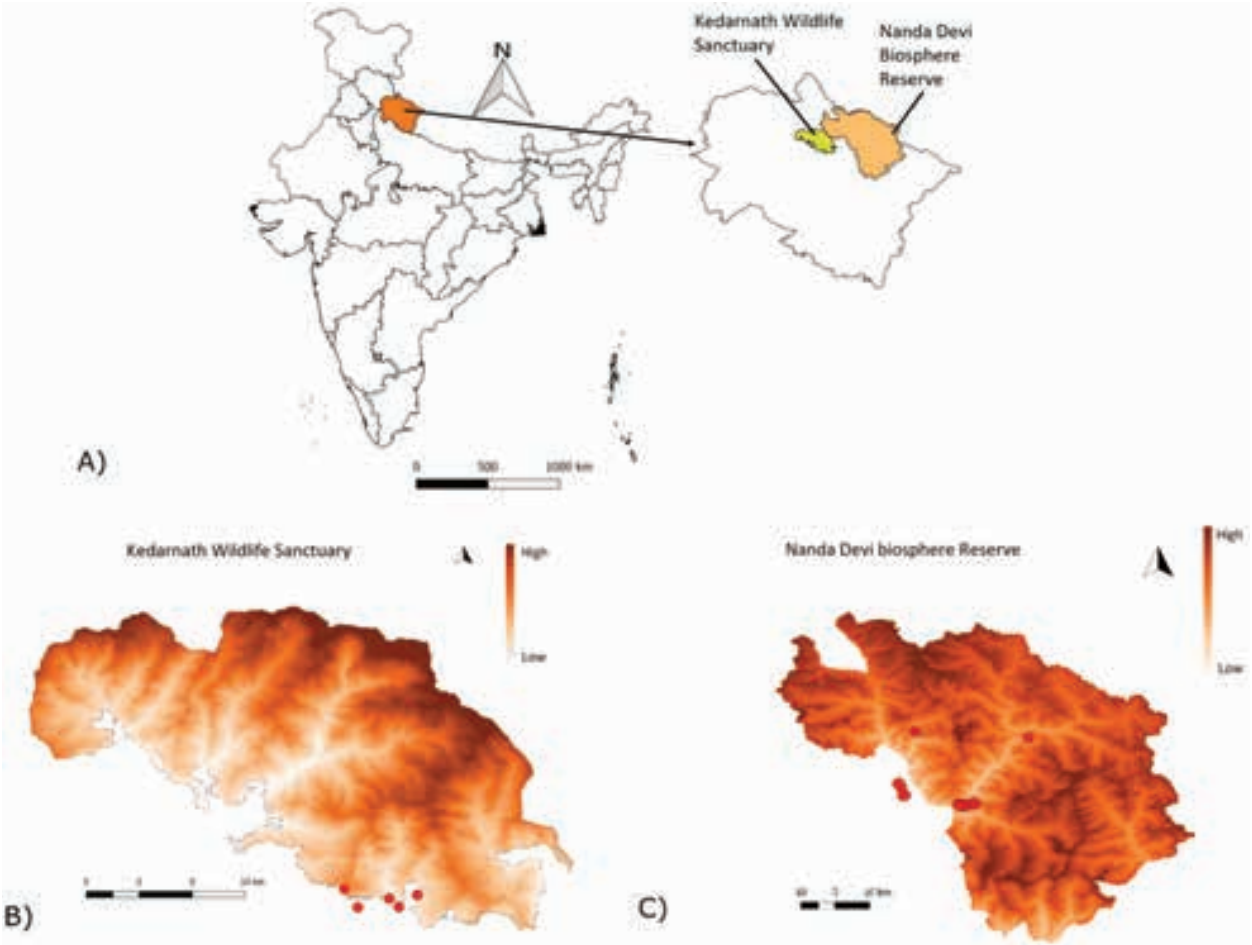

Image 2. Map showing: A—The boundaries of the two protected areas in the west Himalayan state of Uttarakhand | the collection sites (marked in red circles) in B—Kedarnath Wildlife Sanctuary and C—Nanda Devi Biosphere Reserve

each specimen with sterile forceps and transferred to a 96-well microplate preloaded with one drop of 95% ethanol in each well. DNA extraction and sequencing were performed at the Canadian Centre for DNA barcoding, University of Guelph, with standardized high-throughput protocols for DNA barcode amplification and sequencing (Ivanova et al. 2006; deWaard et al. 2008).

Species identification

Identifications of the species in this paper were done with the help of the literature mentioned in the respective species account and also by comparing with the Geometridae collections of the Zoologische Staatssammlung München, Germany, including the famous collection of Claude Herbulot. Voucher specimens are deposited at the Insect collection section of the Wildlife Institute of India, Dehradun. In some cases, DNA barcodes provided additional information on species identity. DNA barcode data are accessible in the public dataset DS-HIMALGEO on BOLD database (https://doi.org/10.5883/DS-HIMALGEO) (Ratnasingham & Hebert 2007, 2013).

Species Account

Subfamily: Ennominae

1. ***Arichanna tramesata*** Moore, 1868 (Image 3:1)

Arichanna tramesata Moore, 1868, Proc. zool. Soc. Lond. 1867:658, pl.33, fig.2 [India: Bengal]

Arichanna tramesata: Hampson (1895), Fauna of British India (Moths) 3: 290

Arichanna tramesata: Wehrli (1939), in Seitz Macrolep. World Suppl. IV: 255

Arichanna tramesata: Sato (1993), Moths of Nepal. Part 2. TINEA. Vol. 13 (Supplement 3). The Japan Heterocerists' Society, Tokyo. Pl. 34/11.

Distribution in India: Bengal, Sikkim, Khasis (Meghalaya); new record from the western Himalaya

2. ***Arichanna sparsa*** (Butler, 1890) (Image 3:2)

Icterodes sparsa Butler, 1890, Entomologist 23:316 [India: Kangra, Dharmsala]

Arichanna sparsa: Prout (1915) in Seitz Macrolep. World IV: 304, pl. 14 b

Arichanna sparsa: Hampson (1895), Fauna of British India (Moths) 3: 294

Arichanna sparsa: Sato (1993), Moths of Nepal. Part 2. TINEA. Vol. 13 (Supplement 3). The Japan Heterocerists' Society, Tokyo. Pl. 34/2.

Distribution in India: Darjeeling (West Bengal), Dharmsala (Himachal Pradesh); new record from the state of Uttarakhand

Genetic data: BIN: BOLD: AAJ8159 (BC ZSM Lep 94382, 94384).

3. ***Blepharoctenucha virescens*** (Butler, 1880) (Image 4:3)

Hemerophila virescens Butler, 1880, Ann. Mag. Nat. Hist. (5) vi. P.126 [India: Darjeeling]

Boarmia virescens: Hampson (1895), Fauna of British India (Moths) 3: 295

Blepharoctenucha virescens: Yazaki (1992), Moths of Nepal. Part 1. TINEA. Vol. 13 (Supplement 2). The Japan Heterocerists' Society, Tokyo. Pl. 10/10.

Distribution in India: Sikkim, Darjeeling (West Bengal), Arunachal Pradesh; new record from western Himalaya

Remarks: The distal parts of the wings show a paler coloration than in the Nepalese specimen figured in Yazaki (1992).

Subfamily: Larentiinae

4. ***Costicoma exangulata*** (Warren, 1909) (Image 3:3)

Perizoma exangulata Warren, 1909, Novit. Zool. xvi: 127 [Kashmir: Srinagar]

Thera exangulata: Prout (1914), in Seitz Macrolep. World Suppl. IV: 217, pl. 8 row l, (113)

Costicoma exangulata: Choi (2000), American Museum Novitates, no.3295: 19

Distribution in India: Kashmir: Srinagar; new record from the state of Uttarakhand (Choi 2000 mentions that the species is found in the "northern part of India", but no other record is found from other Northern Indian states)

Genetic data: BIN: BOLD: ADF3000 (BC ZSM Lep 94548, 94549).

5. ***Dysstroma planifasciata*** (Prout, 1914) (Image 3:4)

Cidaria planifasciata Prout, 1914, in Seitz Macrolep. World IV: 220; pl.13 e [d]; Vol. XII: pl. 32 i [Kashmir: Koksar]

Dysstroma planifasciata: Yazaki (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists' Society, Tokyo: 10; Pl. 162/8.

Distribution in India: Kashmir: Koksar (now in Himachal Pradesh); new record from the state of Uttarakhand

Genetic data: BIN: BOLD:ADF3836 (BC ZSM Lep 94515, 94516).

Remarks: Further research is required to clarify distribution and species delimitation of the species

Table 1. List of species with details of the collection location and the type of forest.

Subfamily	Genus	Species	Author	Location	Lat.	Long.	Elevation (in m)	Forest type
Ennominae	*Arichanna*	*tramesata*	Moore, 1868	NDBR (Lata vill.), KWS (Kanchula, Jatholi	30.492	79.714	2399	MO
Ennominae	*Arichanna*	*sparsa*	Butler, 1890	NDBR (Lata)	30.494	79.713	2320	WMC
					30.494	79.713	2339	WMC
					30.495	79.721	2544	WMC
Ennominae	*Blepharoctenuc-ha*	*virescens*	Butler, 1880	KWS (Anasuya, Jatholi, Kanchula, Mandal)	30.472	79.288	1766	MO
					30.460	79.230	2636	OM
					30.460	79.270	1617	MO
Larentiinae	*Costicoma*	*exangulata*	Warren, 1909	NDBR (Lata gradient)	30.495	79.721	2526	WMC
					30.495	79.727	2913	WMC
					30.496	79.738	2905	WMC
					30.499	79.743	3310	WHBF
Larentiinae	*Dysstroma*	*planifasciata*	Prout, 1914	NDBR (Joshimath, Lata)	30.554	79.547	2107	LLBP
					30.546	79.554	2414	WMC
					30.520	79.559	3141	KO
					30.521	79.559	3152	KO
					30.495	79.727	2913	WMC
					30.496	79.738	2905	WMC
					30.499	79.743	3310	WHBF
					30.499	79.743	3327	WHBF
Larentiinae	*Cidaria*	*basharica*	Bang-Haas, 1927	NDBR (Malari village)	30.684	79.889	3042	Inside village
Larentiinae	*Trichoplites*	*lateritata*	Moore, 1888	NDBR (Lata gradient)	30.495	79.722	2553	WMC
					30.495	79.721	2544	WMC
Larentiinae	*Rheumaptera*	*melanoplagia*	Hampson, 1902	NDBR, KWS	30.522	79.564	2977	WHUOF
					30.520	79.559	3141	KO
Larentiinae	*Photoscotosia*	*dejuncta*		NDBR (Lata, Ghangariya)	30.494	79.728	2766	WMC
					30.500	79.744	3373	WHBF
					30.497	79.749	3775	WHBF
					30.497	79.749	3768	WHBF
					30.699	79.592	3213	Inside village
Larentiinae	*Perizoma*	*conjuncta*	Warren, 1893	NDBR (Joshima-th, Lata)	30.555	79.547	2108	LLBP
					30.495	79.705	2126	LLBP
					30.494	79.705	2152	LLBP
					30.494	79.705	2164	LLBP
					30.495	79.705	2143	LLBP
					30.495	79.727	2913	WMC
					30.496	79.738	2905	WMC
					30.499	79.743	3310	WHBF
Larentiinae	*Perizoma*	*plumbeata*	Moore, 1888	KWS (Gondi)	30.468	79.261	1638	MO
Larentiinae	*Perizoma*	*hockingii*	Butler, 1889	KWS (Shokharak)	30.478	79.216	3067	AR
					30.545	79.554	2433	WMC

NDBR—Nanda Devi Biosphere Reserve | KWS—Kedarnath Wildlife Sanctuary | MO—Mixed Oak | WMC—Western Mix Coniferous | OM—Oak-Maple | WHBF—Western Himalayan Birch-Fir | LLBP—Low level blue Pine | WHUOF—Western Himalayan upper oak-fir | AR—Alpine rhododendron.

pair *Dysstroma planifasciata* and *D. dentifera* (Warren, 1896), the latter described from India/Darjeeling.

6. *Cidaria basharica* Bang-Haas, 1927 (Image 3:5)

Cidaria basharica Bang-Haas, 1927, Horae. Macrolep.1: 93, pl. XI: 20 [India: Poo-Bashahr State, Schipki-la]

Cidaria basharica: Prout (1914), in Seitz, Macrolep. World IV. Suppl (110), pl. 11 b

Cidaria basharica: Yazaki (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists' Society, Tokyo. Pl. 162/16.

Distribution in India: Himachal Pradesh; new record from the state of Uttarakhand

Remarks: Further research is required to clarify distribution and species delimitation of the species pair *Cidaria basharica* and *C. antauges* Prout, 1938, the latter described from Kashmir/Kokser. Wing pattern of our record from Uttarakhand is well matching the figure for a Nepalese specimen in Yazaki (2000), whilst the type of *C. basharica* shows a much narrower medial area. It is not excluded that the populations of Uttarakhand and Nepal belong to *C. antauges*.

7. *Trichoplites lateritiata* (Moore, 1888) (Image 3:6)

Anticlea lateritiata Moore, 1888, in Hewitson & Moore, Descr. new Indian lepid. Insects Colln late Mr Atkinson: 273. [India: Darjeeling]

Trichoplites lateritiata: Yazaki (1993). Moths of Nepal. Part 2. TINEA. Vol. 13 (Supplement 3). The Japan Heterocerists' Society, Tokyo. Pl. 60/2.

Distribution in India: Darjeeling (West Bengal), new record from western Himalaya

8. *Rheumaptera melanoplagia* (Hampson, 1902) (Image 3:7)

Scotosia melanoplagia Hampson, 1902, J. Bombay Nat. Hist. Society 14: 512 [Tibet: Yatong; Sikkim]

Calocalpe melanoplagia: Prout (1941), in Seitz, Macrolep. World XII, pl. 33 h

Calocalpe melanoplagia: Fletcher (1961), Veröff. Zool. Staatssamml. München 6: 171.

Rheumaptera melanoplagia: Yazaki (1995), Moths of Nepal. Part 4. TINEA. Vol. 14 (Supplement 2). The Japan Heterocerists' Society, Tokyo. Pl. 97/20.

Triphosa melanoplagia: Scoble (ed., 1999). Geometrid Moths of the World, a Catalogue.

Distribution in India: Sikkim (Dudgeon); new record from western Himalaya

Genetic data: BIN: BOLD:ADF3132 (BC ZSM Lep 94404)

Remarks: Sanyal et al. 2017 mentions this record by PD. A long series of this species from Western Nepal province shows a broader forewing costal spot in almost all of the >200 specimens.

9. *Photoscotosia dejuncta* Prout, 1937 (Image 3: 8)

Photoscotosia dejuncta Prout, 1937: in Seitz, Macrolep. World IV, Suppl.: 103, pl. 10 d [Kashmir: Gulmarg]

Distribution: Kashmir, Himachal Pradesh, Spiti Valley (Herbulot Collection, ZSM), new record from the state of Uttarakhand

Genetic data: BIN: BOLD:AAE6530 (BC ZSM Lep 94391), BIN-sharing with nominotypical *P. dejuncta*, but slightly diverging.

Remarks: Identified in the collection Herbulot in Zoologische Staatssammlung Munich, Germany, as "*Photoscotosia dejuncta occidens* Herbulot" which apparently is an unpublished manuscript name intended for the populations from Himachal Pradesh which differ from nominotypical *P. dejuncta* by a more greyish coloration and the missing pale costal spot near the forewing apex. This name was used in Dey et al. (2019) without description (nomen nudum). Yazaki (1995) described *Photoscotosia pallidimacula* based on specimens from central Nepal, showing paler forewings and a broadly white hindwing costa. More research is needed to clarify the taxonomy and species delimitation in this group.

10. *Perizoma conjuncta* Warren, 1893 (Image 3:9)

Perizoma conjuncta Warren, 1893: Proc. Zool. Soc. Lond.: 381. [Burma: E Pegu]

Larentia conjuncta: Hampson (1895), Fauna of British India (Moths) 3: 374.

Perizoma conjuncta: Prout (1939), in Seitz, Macrolep. World XII: 279

Perizoma conjuncta: Inoue (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists' Society, Tokyo. Pl. 166/20.

Distribution in India: Khasis (Meghalaya), new record from western Himalaya

Genetic data: BIN: BOLD:ADF4467 (BC ZSM Lep 94466, 94484).

11. *Perizoma plumbeata* (Moore, 1888) (Image 4:1)

Anticlea plumbeata Moore, 1888, Descr. new Indian lepid. Insects Colln. Late Mr. W.S. Atkinson (3): 273.

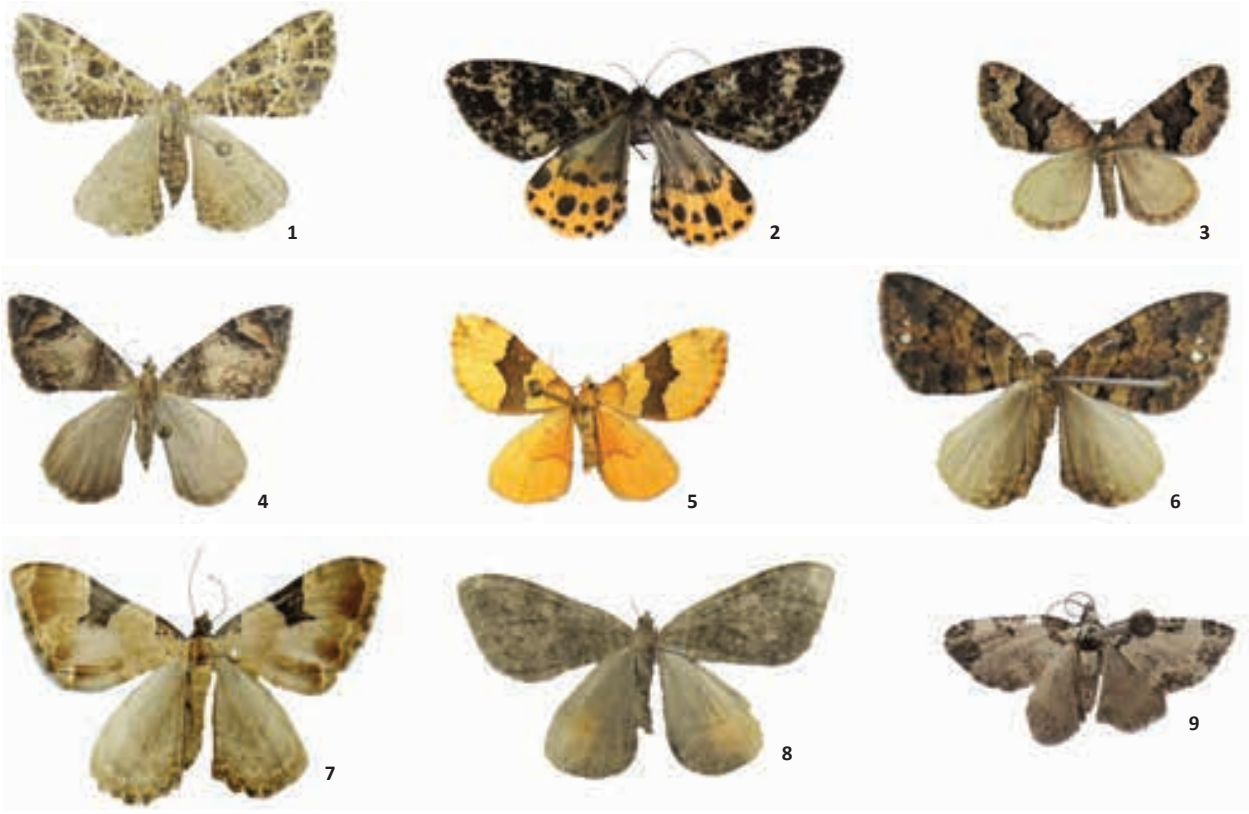

Image 3. Moth species recorded and collected from Nanda Devi Biosphere Reserve: 1—*Arichanna tramesata* | 2—*Arichanna sparsa* | 3—*Costicoma exangulata* | 4—*Dysstroma planifasciata* | 5—*Cidaria basharica* | 6—*Trichoplites lateritata* | 7—*Rheumaptera melanoplagia* | 8—*Photoscotosia dejuncta* | 9—*Perizoma conjuncta*. © Pritha Dey

Image 4. Moth species recorded from Kedarnath Wildlife Sanctuary. 1—*Perizoma plumbeata* | 2—*Perizoma hockingii* | 3—*Blepharoctencha virescens*. © Pritha Dey

[India: Darjeeling]

Larentia plumbeata: Hampson (1895), Fauna of British India (Moths) 3: 376

Perizoma plumbeata: Inoue (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists' Society, Tokyo. Pl. 166/23.

Distribution in India: Himachal Pradesh, Bengal, Sikkim, Arunachal Pradesh; new record from the state of Uttarakhand

12. *Perizoma hockingii* (Butler, 1889) (Image 4: 2)

Eupithecia hockingii Butler, 1889: Illust. typical lepid. Heterocera Colln Br. Mus. 7: 115, pl. 137: 12. [India: Kangra, Dharmsala]

Larentia hockingii: Hampson (1895), Fauna of British India (Moths) 3: 376

Perizoma hockingii: Inoue (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists' Society, Tokyo. Pl. 166/28.

Distribution in India: Sikkim, Dharmsala (Himachal Pradesh); new record from the state of Uttarakhand.

DISCUSSION

Our study clearly highlights the gaps in the existing distributional data for moths, especially in western Himalaya and reiterates the effectiveness of an integrative biodiversity assessment in a hyper-diverse taxon. So far, the moth diversity of the western Himalayan state of Uttarakhand has just been investigated sporadically. Roonwal et al. (1963), a report of the entomological collections of the Forest Research Institute, Dehradun was among the first publications recording moths from this state. Later on, several other publications, as mentioned in the introduction have contributed to the understanding of the diversity and distribution of moths from this western Himalayan state. Sanyal (2015), Sanyal et al. (2017), Dey (2019), and Dey et al. (2019) have focussed on the diversity and distributions of geometrid moths specifically; however, serious gaps still remain as these studies could not cover the entire elevational/habitat range, which would provide a more comprehensive understanding of the diversity and the ecological processes governing their distributions. Recently, global insect decline has been in the spotlight (Hallmann et al. 2017; Lister & Garcia 2018) and it is time that concerted efforts towards documenting and monitoring insect populations are set in place, specifically in the global biodiversity hotspots. Rapid deforestation and urbanization magnify the problem, whereby we might lose critical habitats for the survival of specialised species. Such declines are a sober warning of wider environmental changes, and new distribution records will increase the biological knowledge required to understand the wider impact of such changes. Also, it will work towards fostering increased interest towards moths, which is critical in this endeavour. Some new records reported in this paper from the surroundings of Kedarnath Wildlife sanctuary were a part of a moth-survey project (https://www.rufford.org/projects/pritha-dey/high-altitude-moth-lepidoptera-heterocera-assemblages-assessing-the-diversity-and-potential-bio-indicator-species-in-kedarnath-wildlife-sanctuary-india/) which simultaneously allowed us (a) to document moths from a hitherto unexplored area and (b) to conduct citizen-science workshops to spread awareness on moths. Our findings highlight the need for more such surveys to document the moth diversity across the wide elevation and habitat gradients in the western Himalayan region, where the Oriental and Palearctic biogeographic elements overlap, and which is home to unique biodiversity (Meinertzhagen 1928). Future endeavours of such kind will not only add to the current database, but will help in bringing the spotlight on the need for moth conservation in a fragmented, threatened landscape, in the largest mountain system in the world.

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COMMUNICATION

Butterfly diversity of Putalibazar Municipality, Syangja District, Gandaki Province, Nepal

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Abstract: A study was carried out to find the butterfly species diversity and abundance in Putalibazar Municipality, Syangja, Gandaki, Nepal, from June 2019 to July 2020. Pollard walk method was used for data collection in three different habitat types: forest, agricultural land, and settlement area. The study was performed in all seasons: pre-monsoon, monsoon, post monsoon and winter. A total of 180 butterfly species from 108 genera and six families were recorded. The overall Shannon-Wiener diversity index (H) was 4.48. The highest diversity was represented by the Nymphalidae with 67 species (H= 3.79). Butterfly diversity and species abundance was highest in the forest area (147 species, 1199 individuals; H= 4.47). The highest species richness (109 species) was observed in the monsoon season.

Keywords: Abundance, dominance, Pollard walk method, richness

Nepali abstract: पुतलीबजार नगरपालिका, स्याङ्जा, गण्डकी, नेपालमा पुतली प्रजातिको बबिधिता र प्रचुरता थाहा पाउनका लागि जुन २०१९ देखि जुलाई २०२० सम्म यो अध्ययन सन्चालन गरिएको थियो। पोलार्ड वाक बधि प्रियोग गरि तिन फरक बासस्थान (वन, कृषि जमनि र बासस्थान क्षेत्र) बाट तथ्यांक सङ्कलन गरिएको थियो। यो अध्ययन चार वटै मौसममा (प्रि-मनसुन, मनसुन, पोष्ट-मनसुन र वन्टिर) सन्चालन गरिएको थियो। कुल १८० प्रजातिका पुतलीहरु रेकर्ड गरिएका थिय जुन १०८ जेनेरा र ६ फेमलिीमा सम्बन्धति छन्। कुल स्यानोन-वनिर डाइभर्सटिि इन्डेक्स (□) ४.४८ थियो। सबैभन्दा बढि विविधिता (६७ प्रजाति, □=३.७९) नम्फिालडिी फेमलिबिाट पाइएको थियो। त्यसैगरि, वन क्षेत्रबाट सबैभन्दा बढि विविधिता र प्रचुरता (१४४ प्रजाति, १,१९९ सङ्ख्या र □=४.४७) पाइएको थियो। साथै मनसुनमा सबैभन्दा बढि विविधिता (१०९ प्रजाति) पाइएको थियो। यो अध्ययनले उक्त क्षेत्रमा पुतलीको थप अनुसन्धान र संरक्षण गर्न मद्दत गर्नेछ।

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Author contributions: KN: conceptualization, research design, field work, data collection, species identification, draft review and revision. MSM: research design, field work, data collection, species identification, data analysis and interpretation, manuscript drafting, editing, critical review and revisions.

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INTRODUCTION

Butterflies play crucial roles in pollination and food chains, and they serve as bio-indicators in terrestrial ecosystems (Tiple 2007) of vegetative structure, habitat quality (Sawchik et al. 2005) and climate change (Permesan et al. 1999). India is home to over 1,500 species of butterfly (Tiple 2011), and Nepal of more than 660 species (Smith 2011). The main sources of butterfly research in different parts of Nepal are Smith (1994, 2006, 2011), Khanal (2006, 2008), Bhusal & Khanal (2008), and Acharya & Vijyan (2015). No previous studies have been carried out on butterflies in the Syangja District, hence this study examined species diversity and abundance in Putalibazar municipality, Gandaki, Nepal.

MATERIALS AND METHODS

Study area

The study was carried out in Putalibazar municipality (28.100°N and 83.871°E) from June 2019 to July 2020 covering an area of 146.21km^2. It is surrounded by Kaski District and Tanahu District in the east, Adhikhola rural-municipality, Arjun chaupari rural-municipality, and Bhirkot municipality in the west, Kaski District and Phedikhola rural-municipality in the north, and Biruwa rural-municipality and Bhirkot municipality in the south. The study was carried out in an altitude range of 760 to 835 m, in three habitat types; forest, agriculture land and settlement area. The forest is dominated by *Schima wallichii* and *Castonopsis indica*. Major agriculture crops planted in the study area are maize, rice, millet, and the settlement is near the forest area and agriculture land. The study area map is shown in Figure 1.

Butterfly survey

Pollard walk method was used for the butterfly survey (Pollard 1977). Transects of 300–500 m, two in each habitat type were set up. Butterflies were observed within a 5-m width; 2.5 m to each side of the transect. Butterflies were recorded in all the four seasons: pre-Monsoon (March–May), monsoon (June–September), post-monsoon (October–November), and winter (December–February). Field visits were made twice a month, from 0900 h to 1600 h. Sunny days were

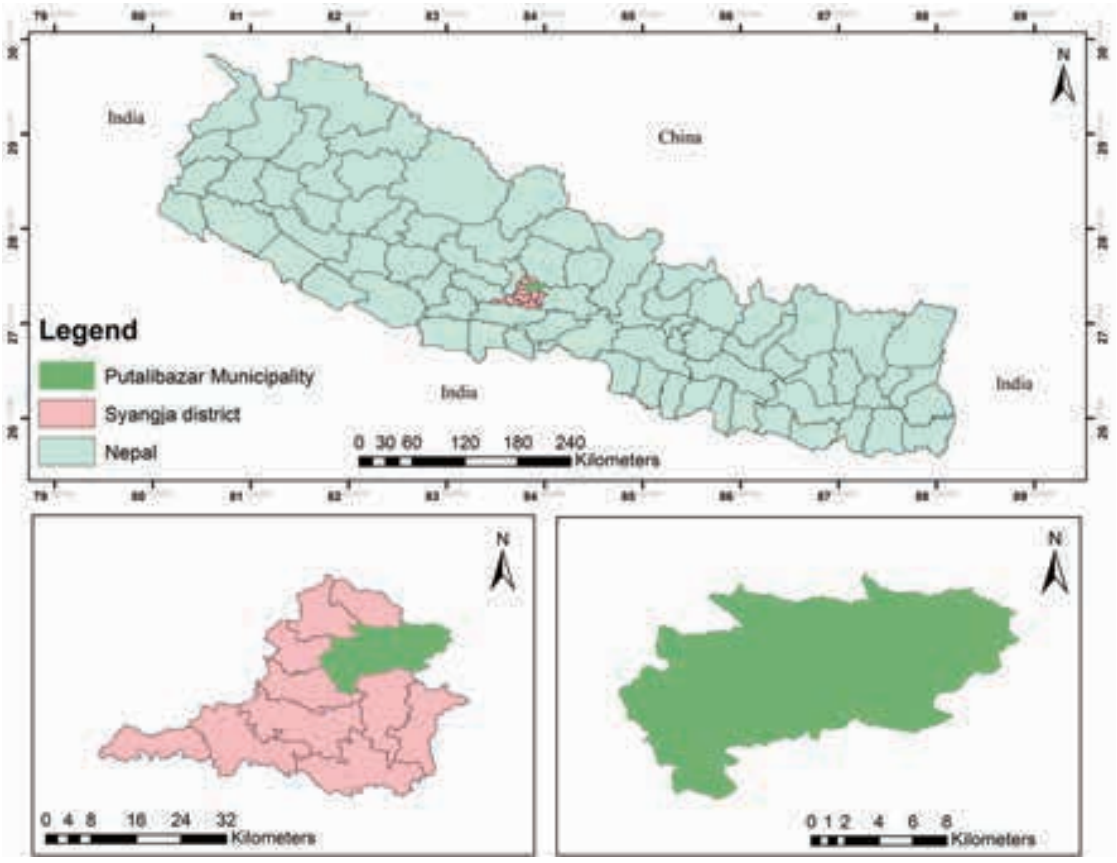

Figure 1. Study area map showing Putalibazar municipalitity.

preferred to ensure maximum detection of butterflies during the survey. Direct field observations followed by photography were used to record species. Field guides by Smith (2011) and Smith et al. (2016) were used to identify butterflies in the field. Photographs were taken by Smartphone (Samsung Galaxy J7 Nxt and Samsung Galaxy J7 Prime 2). Species that were difficult to identify in the field were later identified through internet references (https://www.ifoundbutterflies.org/), (https://www.projectnoah.org/), and consulting with experts. Butterflies are classified based on (Kehimkar 2016). Local status of the butterfly is determined based on (Tiple et al. 2005) as: very common (>100 sightings), common (50–100 sightings), fairly common (15–50 sightings), rare (2–15 sightings), and very rare (<2 sightings). National status (Nepal) is based on Smith (2011) and Smith et al. (2016).

Data analysis

Species richness of butterflies was determined based on the total number of species recorded. Diversity was calculated using the Shannon-Wiener diversity index, and species evenness was calculated using Shannon equitability:

$$\text{Shannon-Wiener diversity index (H)} = -\sum_{i=1}^{n} Pi * \ln Pi$$

$$\text{Shannon equitability (E)} = \frac{H}{Hmax}, \text{ here, Hmax} = \ln(S)$$

Where, *Pi*= Proportion of individuals belonging to the i^{th} species, *n*= total number of individuals, S= number of species. Data were analyzed with MS excel software.

RESULTS AND DISCUSSION

A total of 180 butterfly species under 108 genera and six families were recorded during the survey (Table 1, Images 1–179). The overall Shannon-Wiener diversity index was 4.48. Species richness, abundance, evenness and diversity indices are given in Table 2 and Table 3.

A total of 147 species of butterflies were found in the forest, 100 in agricultural land, and 39 in the settlement area; 25 species were found in all three habitat types, and 77 species were found only in the forest. Species composition in different habitat types is shown in Table 1 and Figure 2. Of the six recorded butterfly families, Nymphalidae represented the maximum species richness with 67 species, followed by Lycaenidae (42 species), Hesperiidae (26 species), Pieridae (23 species), Papilionidae (16 species), and Riodinidae (6 species). The family-wise composition of butterfly species and genera is given in (Figure 3). The highest species richness was observed in monsoon season comprising 109 species, followed by pre-monsoon (76 species), post-monsoon (63 species), and winter (22 species). Season-wise species richness is mentioned in Figure 4.

The diversity of butterfly species is higher (H= 4.48) in this small study area. Among 660 species of butterflies in Nepal (Smith 2011), butterfly species recorded in the study area which is about 27% of the total butterfly species in Nepal. Among the recorded species during the survey, a total of 13 species (7%) (Tree Yellow *Gandaca harina*, Blue Imperial *Ticherra acte*, Chocolate Royal *Remelena jangala*, Green Oakblue *Arhopala eumolphus*, Indian Purple Sapphire *Heliophorus indicus*, Tailed Judy *Abisara neophron*, Autumn Leaf *Doleschallia bisaltide*,

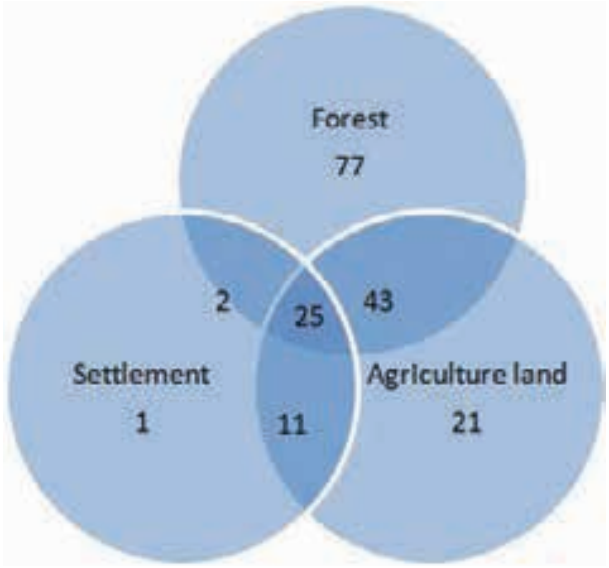

Figure 2. Butterfly species composition in different habitat types

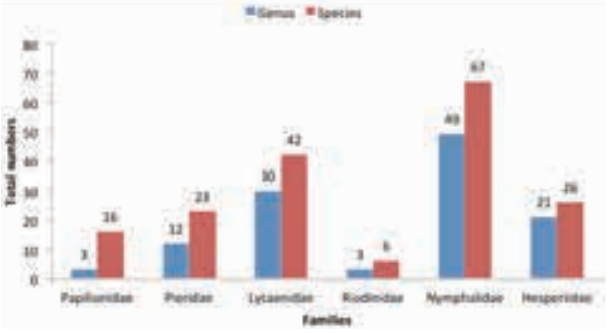

Figure 3. Family-wise composition of butterfly genera and species.

Table 1. List of butterflies recorded from Putalibazar Municipality, Syangja.

	Scientific names	Common names	Habitat types	Local status	Status (Nepal)
Papilionidae (16)					
1.	*Graphium agamemnon* Linnaeus, 1758	Tailed Jay	A & S	R	C
2.	*Graphium cloanthus* (Westwood, 1841)	Glassy Bluebottle	F	R	FC
3.	*Graphium doson* Felder & Felder, 1864	Common Jay	A & F	FC	FC
4.	*Graphium sarpedon* (Linnaeus, 1758)	Common Bluebottle	A & S	FC	C
5.	*Papilio arcturus* (Westwood, 1842)	Blue Peacock	A & S	R	C
6.	*Papilio bianor* Cramer, 1777	Common Peacock	F & S	R	C
7.	*Papilio clytia dissimilis* Linnaeus, 1758	Common Mime	F	R	FC
8.	*Papilio demoleus* (Linnaeus, 1758)	Lime Swallowtail	A, F & S	FC	VC
9.	*Papilio helenus* (Linnaeus, 1758)	Red Helen	F	R	C
10.	*Papilio machaon* (Linnaeus, 1758)	Common Yellow Swallowtail	A	R	C
11.	*Papilio memnon* Linnaeus, 1758	Great Mormon	A & F	FC	C
12.	*Papilio nephelus* Boisduval, 1836	Yellow Helen	F	R	FC
13.	*Papilio paris* Linnaeus, 1758	Paris Peacock	A & F	FC	C
14.	*Papilio polytes* Linnaeus, 1758	Common Mormon	A, F & S	FC	VC
15.	*Papilio protenor* Cramer, 1775	Spangle	A & F	FC	C
16.	*Triodes aeacus* (Felder & Felder, 1860)	Common Birdwing	F	R	NE
Pieridae (23)					
17.	*Appias lalage lalage* (Doubleday, 1842)	Himalayan Spot Puffin	F	VR	NE
18.	*Appias lyncida* (Cramer, 1779)	Chocolate Albatross	A & S	FC	FC
19.	*Catopsilia pomona crocale* Fabricius, 1775	Common Emigrant	A, F & S	FC	VC
20.	*Catopsilia pomona pomona* (Fabricius, 1775)	Lemon Emigrant	A, F & S	FC	VC
21.	*Catopsilia pyranthe* Linnaeus, 1758	Mottled Emigrant	A & F	FC	VC
22.	*Cepora nadina* (Lucas, 1852)	Lesser Gull	A & F	R	FC
23.	*Cepora nerissa* Fabricius, 1775	Common Gull	A & F	FC	C
24.	*Colias fieldii* (Menetries, 1855)	Dark Clouded Yellow	A & S	R	C
25.	*Delias acalis* (Godart, 1819)	Red-breast Jezebel	A & F	R	FC
26.	*Delias descombesi* (Boisduval, 1836)	Red-spot Jezebel	F	R	LC
27.	*Delias eucharis* (Drury, 1773)	Common Jezebel	F & S	R	FC
28.	*Delias hyparete* (Linnaeus, 1758)	Painted Jezebel	A & S	R	VC
29.	*Delias posithoe* (Linnaeus, 1767)	Red-base Jezebel	A & F	R	VC
30.	*Eurema blanda* (Boisduval, 1836)	Three-spot Grass Yellow	A, F & S	C	VC
31.	*Eurema brigitta* (Stoll, 1780)	Small Grass Yellow	A, F & S	C	C
32.	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	A, F & S	VC	VC
33.	*Eurema laeta* (Boisduval, 1836)	Spotless Grass Yellow	A & S	FC	C
34.	*Gandaca harina* (Horsfield, 1829)	Tree Yellow	F	R	R
35.	*Genopteryx rhamni* (Linnaeus, 1758)	Common Brimstone	F	R	C
36.	*Hebomoia glaucippe* (Linnaeus, 1758)	Great Orange Tip	A & F	FC	FC
37.	*Ixias pyrene* (Linnaeus, 1764)	Yellow Orange Tip	A & F	FC	C
38.	*Pieris canidia* (Linnaeus,1768)	Indian Cabbage White	A, F & S	VC	VC
39.	*Pontia daplidice* (Linnaeus, 1758)	Bath White	A & F	FC	C
Lycaenidae (42)					
40.	*Acytolepis puspa* (Horsfield, 1828)	Common Hedge Blue	A	R	VC
41.	*Arhopala centaurus* (Fabricius, 1775)	Centaur Oakblue	F	FC	VC
42.	*Arhopala eumolphus* Cramer, 1780	Green Oakblue	F	R	R
43.	*Arhopala oenea* (Hewitson, 1869)	Hewitson's Dull Oakblue	F	R	FC

	Scientific names	Common names	Habitat types	Local status	Status (Nepal)
44.	*Arhopala paramuta* (D. Niceville, 1884)	Hooked Oakblue	F	R	VC
45.	*Castalius rosimon* Fabricius, 1775	Common Pierrot	A & F	FC	VC
46.	*Catapaecilma major* (Druce, 1895)	Common Tinsel	F	R	FC
47.	*Catochrysops strabo* (Fabricius, 1793)	Forget-me-not Blue	A	FC	VC
48.	*Celastrina lavenduralis* (Moore, 1877)	Plain Hedge Blue	A	R	NE
49.	*Chliaria othona* (Hewitson, 1865)	Orchid Tit	F	R	C
50.	*Curetis acuta* Moore, 1877	Angled Sunbeam	F	R	NE
51.	*Curetis bulis* (Westwood, 1851)	Bright Sunbeam	F	R	C
52.	*Euchrysops cnejus* (Fabricius, 1798)	Gram Blue	A	FC	C
53.	*Everes lacturnus* (Godart, 1824)	Indian Cupid	A & F	FC	VC
54.	*Heliophorus epicles* (Godart, 1824)	Purple Sapphire	A & F	FC	VC
55.	*Heliophorus indicus* (Fruhstorfer, 1908)	Indian Purple Sapphire	F	R	R
56.	*Heliophorus sena* (Kollar, 1844)	Sorrel Sapphire	F	R	LC
57.	*Iraota timoleon* (Stoll, 1790)	Silverstreak Blue	F	R	FC
58.	*Jamides bochus* (Stoll, 1782)	Dark Cerulean	A	R	C
59.	*Jamides celeno* (Cramer, 1775)	Common Cerulean	A, F & S	FC	VC
60.	*Lampides boeticus* (Linnaeus, 1767)	Pea Blue	A & S	FC	VC
61.	*Lestranicus transpectus* (Moore, 1879)	White-banded Hedge Blue	A	R	C
62.	*Loxura atymnus* Stoll, 1780	Yamfly	A	R	FC
63.	*Megisba malaya* (Horsfield, 1828)	Malayan	A	R	FC
64.	*Poritia hewitsoni* (Moore, 1866)	Common Gem	F	R	NE
65.	*Prosotas dubiosa* (Semper, 1879)	Tailless Line Blue	F	R	C
66.	*Prosotas nora* (Felder, 1860)	Common Line blue	F	FC	VC
67.	*Pseudozizeeria maha* (Kollar, 1844)	Pale Grass Blue	A, F & S	VC	VC
68.	*Rapala manea* (Hewitson, 1863)	Slate Flash	F	R	VC
69.	*Rapala nissa* (Kollar, 1844)	Common Flash	F	FC	VC
70.	*Rapala pheretima* (Hewitson, 1863)	Copper Flash	F	R	C
71.	*Rapala rectivitta* (Moore, 1879)	Shot Flash	F	R	FC
72.	*Remelena jangala* (Horsfield, 1829)	Chocolate Royal	F	VR	R
73.	*Spindasis lohita* (Horsfield, 1829)	Long-banded Silverline	F	R	C
74.	*Spindasis syama* Horsfield, 1829	Club Silverlines	F	R	C
75.	*Surendra quercetorum* (Moore, 1858)	Common Acacia Blue	F	VR	C
76.	*Taraka hamada* (Druce, 1875)	Forest Pierrot	F	R	NE
77.	*Ticherra acte* (Moore, 1858)	Blue Imperial	F	VR	R
78.	*Udara dilectus* (Moore, 1879)	Pale Hedge Blue	A & F	FC	VC
79.	*Zeltus amasa* (Hewitson, 1865)	Fluffy Tit	F	R	FC
80.	*Zizeeria karsandra* (Moore, 1865)	Dark Grass Blue	A & F	FC	NE
81.	*Zizina otis* (Fabricius, 1787)	Lesser Grass Blue	A & F	FC	C
Riodinidae (6)					
82.	*Abisara bifasciata* Moore, 1877	Plum Judy	F	R	FC
83.	*Abisara fylla* (Westwood, 1851)	Dark Judy	A	R	VC
84.	*Abisara neophron* (Hewitson, 1861)	Tailed Judy	F	R	R
85.	*Dodona egeon* (Westwood, 1851)	Orange Punch	F	R	C
86.	*Dodona eugenes* Bates, 1868	Tailed Punch	F	R	C
87.	*Zemeros flegyas* Cramer, 1780	Punchinello	A & F	FC	VC
Nymphalidae (67)					
88.	*Abrota ganga* Moore, 1858	Sergeant Major	F	R	FC
89.	*Acraea terpsicore* Linnaeus, 1758	Tawny Coster	F	R	FC

	Scientific names	Common names	Habitat types	Local status	Status (Nepal)
90.	*Aglais cashmirensis* (Kollar, 1844)	Indian Tortoiseshell	A, F & S	FC	VC
91.	*Argynnis childreni* (Gray, 1831)	Large Silverstripe	F	R	C
92.	*Argynnis hyperbius* (Linnaeus, 1763)	Indian Fritillary	A	R	VC
93.	*Athyma nefte* Cramer, 1780	Color Sergeant	F	R	C
94.	*Athyma perius* Linnaeus, 1758	Common Sergeant	A & F	FC	VC
95.	*Athyma ranga* Moore, 1858	Blackvein Sergeant	F	R	R
96.	*Athyma selenophora* (Kollar, 1844)	Staff Sergeant	A & F	FC	C
97.	*Cethosia biblis* (Drury, 1773)	Red Lacewing	F	R	FC
98.	*Cethosia cyane* (Drury, 1773)	Leopard Lacewing	F	R	R
99.	*Charaxes bernardus* (Fabricius, 1793)	Tawny Rajah	F	VR	LC
100.	*Chersonesia risa* (Doubleday, 1848)	Common Maplet	A & F	FC	FC
101.	*Cupha erymanthis* Drury, 1773	Rustic	F	R	C
102.	*Cyrestis thyodamas* Boisduval, 1836	Common Map	A & F	FC	VC
103.	*Danaus chrysippus* Linnaeus, 1758	Plain Tiger	A, F & S	FC	VC
104.	*Danaus genutia* (Cramer, 1779)	Common Tiger	A, F & S	FC	VC
105.	*Discophora sondaica* Boisduval, 1836	Common Duffer	F	R	FC
106.	*Doleschallia bisaltide* Cramer, 1777	Autumn Leaf	F	VR	R
107.	*Elymnias malelas* (Hewitson, 1863)	Spotted Palmfly	A, F & S	R	C
108.	*Euploea core* (Cramer, 1780)	Common Indian Crow	A, F & S	FC	VC
109.	*Euploea mulciber* (Cramer, 1777)	Striped Blue Crow	A & F	FC	VC
110.	*Euthalia aconthea* (Cramer, 1777)	Common Baron	A & F	FC	C
111.	*Euthalia lubentina* (Cramer, 1777)	Gaudy Baron	F	R	R
112.	*Hestinalis nama* (Doubleday, 1844)	Circe	A & F	R	C
113.	*Hypolimnas bolina* Linnaeus, 1758	Great Eggfly	A & F	R	C
114.	*Hypolimnas misippus* (Linnaeus, 1764)	Danaid Eggfly	F	VR	R
115.	*Junonia almana* Linnaeus, 1758	Peacock Pansy	A & S	FC	VC
116.	*Junonia altites* (Linnaeus, 1763)	Grey Pansy	A, F & S	FC	C
117.	*Junonia iphita* (Cramer, 1779)	Chocolate Pansy	A & F	FC	VC
118.	*Junonia lemonias* Linnaeus, 1758	Lemon Pansy	A, F & S	FC	VC
119.	*Junonia orithya* (Linnaeus, 1758)	Blue Pansy	A & F	R	VC
120.	*Kallima inachus* (Doyere, 1840)	Orange Oakleaf	F	FC	C
121.	*Kaniska canace* (Linnaeus, 1763)	Blue Admiral	F	R	C
122.	*Lethe europa* Fabricius, 1787	Bamboo Treebrown	A & F	FC	C
123.	*Lethe confusa* Aurivillius, 1897	Banded Treebrown	A & F	FC	VC
124.	*Lethe mekera* (Moore, 1858)	Common Red Forester	F	FC	NE
125.	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	A, F & S	FC	VC
126.	*Melanitis phedima* (Cramer, 1780)	Dark Evening Brown	A, F & S	FC	C
127.	*Mycalesis francisca* Stoll, 1780	Lilacine Bushbrown	F	FC	C
128.	*Mycalesis malsara* (Moore, 1858)	White-line Bushbrown	A & F	R	C
129.	*Mycalesis perseus* Fabricius, 1775	Common Bushbrown	A, F & S	FC	VC
130.	*Mycalesis visala* Moore, 1858	Long-brand Bushbrown	A & F	FC	C
131.	*Nemetis chandica* Moore, 1858	Angled Red Forester	F	FC	FC
132.	*Neptis cartica* Moore, 1872	Plain Sailer	F	R	C
133.	*Neptis hylas* Linnaeus, 1758	Common Sailer	A, F & S	FC	VC
134.	*Neptis soma* Moore, 1858	Creamy Sailer	F	R	C
135.	*Orsotriaena medus* (Fabricius, 1775)	Jungle Brown	A & F	FC	VC
136.	*Pantoporia hordonia* (Stoll, 1790)	Common Lascar	A & F	FC	VC
137.	*Parantica aglea* (Stoll, 1782)	Glassy Tiger	A, F & S	FC	VC

	Scientific names	Common names	Habitat types	Local status	Status (Nepal)
138.	*Phalanta phalanta* Drury, 1773	Common Leopard	A & S	R	C
139.	*Polyura athamas* Drury, 1773	Common Nawab	F	R	VC
140.	*Sephisa Chandra* (Moore, 1858)	Eastern Courtier	F	R	FC
141.	*Stibochiona nicea* (Gray, 1846)	Popinjay	F	R	FC
142.	*Symbrenthia hypselis* (Godart, 1824)	Spotted Jester	A	R	C
143.	*Symbrenthia lilaea* (Hewitson, 1864)	Common Jester	A & F	FC	VC
144.	*Symbrenthia niphanda* Moore, 1872	Blue-tail Jester	F	R	FC
145.	*Tanaecia julii* Lesson, 1837	Common Earl	F	FC	C
146.	*Tanaecia lepidea* (Butler, 1868)	Grey Count	A & F	FC	VC
147.	*Tirumala limniace* (Cramer, 1775)	Blue Glassy Tiger	A & F	R	C
148.	*Tirumala septentrionis* (Butler, 1874)	Dark Blue Tiger	A	R	C
149.	*Vagrans egista* (Cramer, 1780)	Vagrant	F	R	C
150.	*Vanessa cardui* (Linnaeus, 1758)	Painted Lady	A	R	VC
151.	*Vanessa indica* (Herbst, 1794)	Indian Red Admiral	A, F & S	FC	VC
152.	*Ypthima baldus* Fabricius, 1775	Common Five-ring	A, F & S	VC	VC
153.	*Ypthima huebneri* Kirby, 1871	Common Four-ring	A, F & S	C	VC
154.	*Ypthima newara* Moore, 1875	Newari Three-ring	A & F	FC	C
Hesperiidae (26)					
155.	*Aeromachus pygmaeus* (Fabricius, 1775)	Pygmy Scrub Hopper	F	R	R
156.	*Ancistroides nigrita* (Latreille, 1824)	Chocolate Demon	A	VR	NE
157.	*Borbo bevani* (Moore, 1878)	Bevan's Swift	A & S	R	VC
158.	*Borbo cinnara* (Wallace, 1866)	Rice Swift	A	R	C
159.	*Burara harisa* (Moore, 1866)	Orange Awlet	S	R	NE
160.	*Burara jaina* (Moore, 1866)	Orange Awl	F & S	R	NE
161.	*Caltoris tulsi* D. Niceville, 1884	Purple Swift	F	R	FC
162.	*Celaenorrhinus munda* (Moore, 1884)	Himalayan Spotted Flat	F	VR	FC
163.	*Erionota torus* Evans, 1941	Sikkim Palm Red-eye	F	VR	FC
164.	*Halpe homolea* (Hewitson, 1868)	Common Ace	F	R	FC
165.	*Hasora badra* (Moore, 1858)	Common Awl	F	R	R
166.	*Iambrix salsala* (Moore, 1866)	Chestnut Bob	A & F	R	C
167.	*Matapa aria* (Moore, 1865)	Common Red-eye	A	VR	FC
168.	*Notocrypta curvifascia* (C. & R. Felder, 1862)	Restricted Demon	A & F	R	VC
169.	*Parnara guttata* (Bremer & Grey, 1852)	Straight Swift	A & F	R	VC
170.	*Potanthus pseudomaesa* (Moore, 1881)	Indian Dart	F	R	VC
171.	*Potanthus trachala tytleri* Evans, 1914	Detached Dart	A	R	NE
172.	*Pseudocoladenia dan* (Fabricius, 1787)	Fulvous Pied Flat	F	R	C
173.	*Sarangesa dasahara* (Moore, 1866)	Common Small Flat	A & F	FC	C
174.	*Sebastonyma dolopia* (Hewitson, 1868)	Tufted Ace	F	R	FC
175.	Spialia galba (Fabricius, 1793)	Indian Skipper	A	FC	C
176.	*Tagiades litigiosa* Moschler, 1878	Water Snow Flat	F	R	C
177.	*Tagiades menaka* (Moore, 1866)	Spotted Snow Flat	F	R	C
178.	*Telicota bambusae* Moore, 1878	Dark Palm Dart	A	R	C
179.	*Telicota colon* Fabricius, 1775	Pale Palm Dart	F	R	FC
180.	*Udaspes folus* (Cramer, 1775)	Grass Demon	A	R	VC

VC—Very Common | FC—Fairly Common | LC—Locally Common | C—Common | R—Rare | VR—Very Rare | NE—Not Evaluated | F—Forest | A—Agriculture land | S—Settlement area

Table 2. Species richness, abundance, evenness, and diversity indices for different habitat types.

Habitat types	Species richness	Species abundance	Species evenness	Shannon-Wiener diversity index
Forest	147	1,199	0.89	4.47
Agriculture land	100	849	0.90	4.16
Settlement	39	274	0.89	3.28

Table 3. Species richness, abundance, evenness, and diversity indices for each butterfly family.

	Family name	Species richness	Species abundance	Species evenness	Shannon-Wiener Diversity index
1.	Papilionidae	16	237	0.89	2.48
2.	Pieridae	23	587	0.76	2.37
3.	Lycaenidae	42	405	0.74	2.77
4.	Roidinidae	6	25	0.73	1.32
5.	Nymphalidae	67	911	0.90	3.79
6.	Hesperiidae	25	157	0.90	2.93
Total		180	2,322	0.86	4.48

Blackvein Sergeant *Athyma ranga*, Danaid Eggfly *Hypolimnas misippus*, Gaudy Baron *Euthalia lubentina*, Leopard Lacewing *Cethosia cyane*, Common Awl *Hasora badra*, and Pygmy Scrub Hopper *Aeromachus pygmaeus* are rare for Nepal (Smith 2011; Smith et al. 2016). Also, 62 species (34 %) are common, 57 species (32 %) are very common, 33 species (18 %) are fairly common, three species (3 %) are locally common for Nepal, and 12 species (6 %) are not evaluated (Smith 2011; Smith et al. 2016) (Table 1; Figure 5). On behalf of the local status of recorded butterflies, 12 species (7 %) were found to be very rare, followed by rare 96 species (53 %), fairly common 65 species (36 %), common 3 species (2 %), and very common four species (2 %) in the study area (Table 1; Figure 6).

Nymphalidae represented the highest Shannon-Wiener diversity index (H= 3.79, 67 species) which means high species diversity, followed by Hesperiidae (H= 2.93), Lycaenidae (H= 2.77), Papilionidae (H= 2.48), Pieridae (H= 2.37), and Riodinidae (H= 1.32). The highest species abundance was shown by Pieridae (587 individulals), followed by Satyridae (466 individuals), Nymphalidae (911 individuals), Lycaenidae (405 individuals), Papilionidae (237 individuals), Hesperiidae (157 individuals), and Riodinidae (25 individuals). Single individuals of Common Birdwing *Troides Helena*, Himalayan Spot Puffin *Appias lalage lalage*, Blue Emperial *Ticherra acte*, Chocolate Royal *Remelena jangala*, Common Acacia Blue *Surendra quercetrum*, Autumn Leaf *Doleschallia bisaltide*, Danaid Eggfly

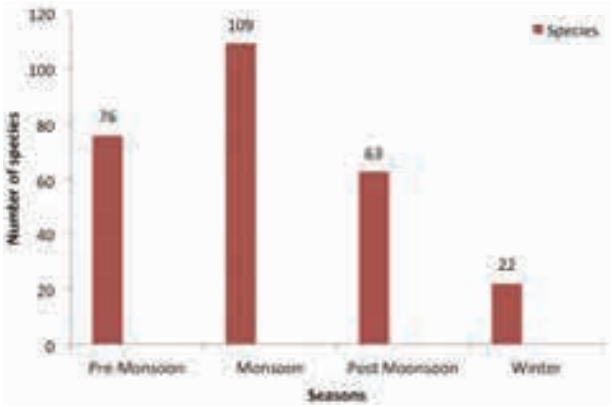

Figure 4. Season-wise species richness of butterfly.

Hypolimnas misippus, Chocolate Demon *Ancistroides nigrita*, Common Red-eye *Matapa aria*, Himalayan Spotted Flat *Celaenorrhinus munda*, Sikkim Palm Red-eye *Erionota torus*, and Tawny Rajah *Charaxes bernardus* were recorded in forest habitat.

The Shannon-Wiener diversity index for forest was 4.47, which represented the high species diversity, may be due to high plant diversity (Bair & Launar 1997; Paddhye et al. 2006). The highest species richness was observed in monsoon season, which might be due to high rainfall and humidity that results in high plant diversity (Bhusal & Khanal 2008; Acharya & Vijayan 2015).

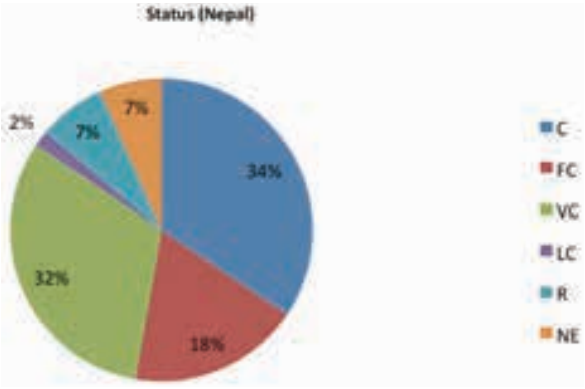

Figure 5. National status of recorded butterflies.

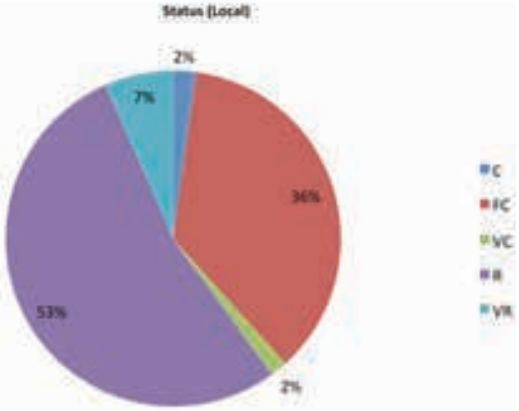

Figure 6. Local status of recorded butterflies.

CONCLUSION

The present study provided a species diversity assessment of butterflies in the study area. Regular monitoring and study would be needed to update the butterfly species checklist in this area. No butterfly conservation activities were performed in the study area. Hence, effective conservation policies and activities should be employed by local government to preserve this high butterfly diversity.

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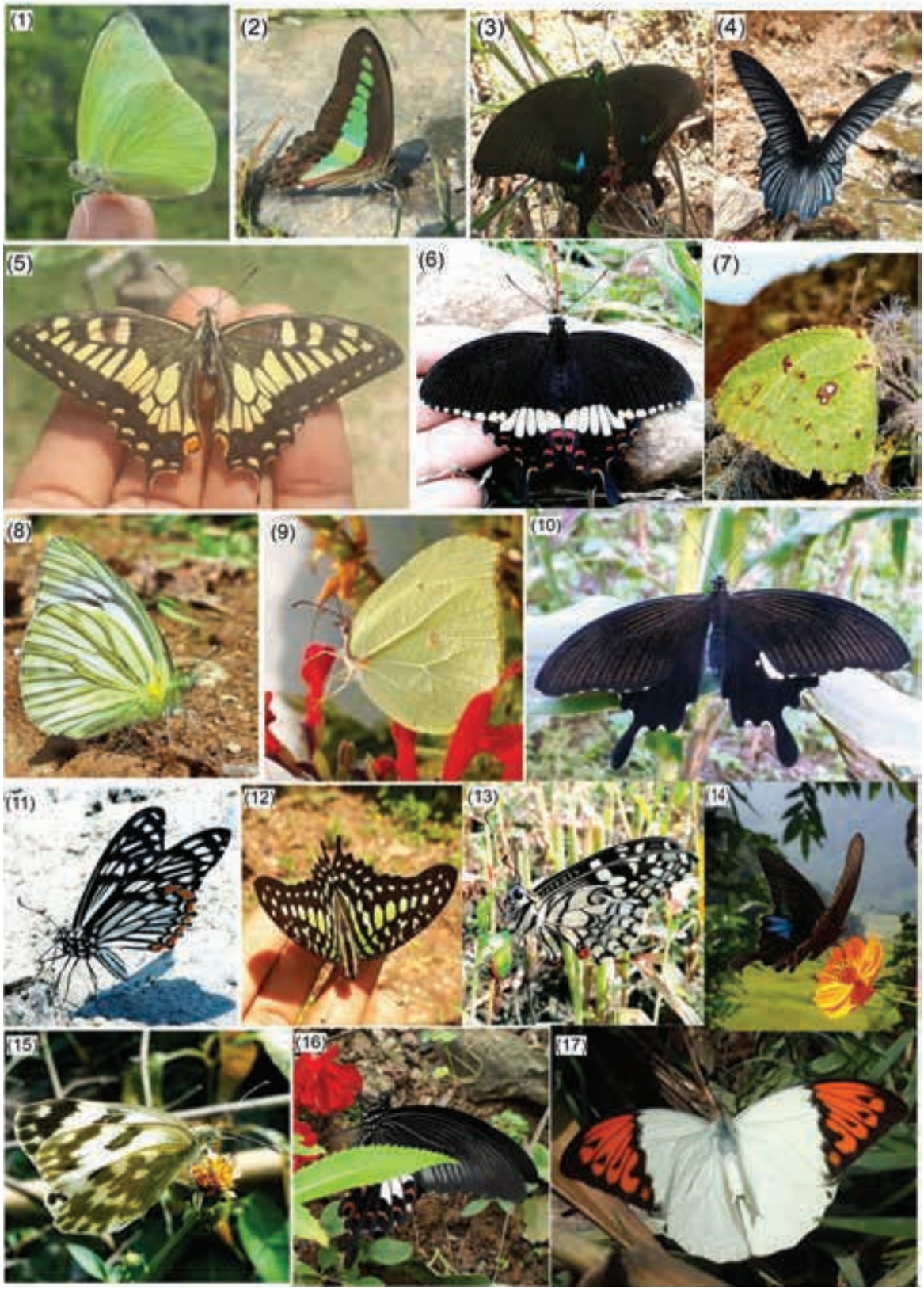

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COMMUNICATION

New records and distribution extension of *Nassarius persicus* (Martens, 1874) and *N. tadjallii* Moolenbeek, 2007 (Mollusca: Gastropoda: Nassariidae) to India

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Abstract: We report new findings of live specimens of *Nassarius persicus* (Martens, 1874) and *N. tadjallii* Moolenbeek, 2007, extending their range to the Gulf of Kachchh, Gujarat, India. The known distribution of both species was limited: *N. persicus* was distributed in the Persian Gulf, Gulf of Oman, and Karachi in Pakistan; *N. tadjallii* was reported from the Persian Gulf and the Gulf of Oman. We also provide comprehensive taxonomic descriptions of both species, along with additional morphological and ecological information.

Keywords: Intertidal mudflats, new records, Gujarat, Gulf of Kachchh Marine Sanctuary

Abbreviations: BNHS—Bombay Natural History Society, Mumbai, India | MNHN—Muséum national d'Histoire naturelle, Paris, France | WoRMS—World Register of Marine Species.

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Author details: Sayali Nerurkar is pursuing her doctoral work on taxonomy and phylogeny of family Nassariidae from India in Bombay Natural History Society, Mumbai. Dr. Deepak Apte is the Executive Director, Srushti Conservation Foundation and is specialized in molluscan taxonomy, biodiversity and Marine Ecology.

Author contributions: DA and SN carried out field work in Gulf of Kutchch, Gujarat. SN identified the species and prepared the manuscript. DA assisted in the preparation of the manuscript and provided photographs of live animals.

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INTRODUCTION

Nassarius Duméril, 1805 (Gastropoda: Nassariidae) is the most diverse genus within the subfamily Nassariinae and limited to the Indo-West Pacific (Galindo et al. 2016; Dekker et al. 2016). Information on the members of this genus from the Indian subcontinent, a major ecoregion of the Western Indo-Pacific, however, is scarce (Nerurkar et al. 2020). In this paper, for the first time, we report the occurrence of many living specimens of *Nassarius persicus* (Martens, 1874) and *Nassarius tadjallii* Moolenbeek, 2007 from the intertidal reef associated mud-flats of the Gulf of Kachchh, Gujarat, India. We also provide a complete taxonomic description for both species, along with additional information about morphological characters which are previously unknown (radula and operculum) for further reference.

Nassarius persicus was earlier reported from the Persian Gulf and the Gulf of Oman, a single record from Aden, Yemen, should be confirmed as it is out of the expected range for this species. This species is also found in Karachi, Pakistan (Cernohorsky 1984). This species is a conspicuous member of the intertidal reef community within the Gulf of Kachchh, Gujarat; however, it was misidentified as *N. arcularia plicatus* (Röding, 1798) (Ghosh 2008: pl. 1, figs. 5–6) and *N. olivaceus* (Bruguière, 1789) (Dave & Mankodi 2008: fig. 1) previously.

Nassarius tadjallii is currently known only from the Persian Gulf and the Gulf of Oman. This species is very similar to *N. marmoreus* (A. Adams, 1852), *N. javanus* (Schepman, 1891), and *N. thachorum* Dekker et al., 2016.

MATERIALS AND METHODS

Taxon sampling: Specimens of both species were found and handpicked at low tide during the present study, intertidally, up to 1 m depth, at different localities in the district Devbhumi Dwarka, Gujarat, India. Live animals were photographed in the field before collection (IMAGE 1). Animals were preserved in 96–98% ethanol and voucher specimens are housed in the museum of Bombay Natural History Society (BNHS).

Morphological analyses for primary identification: A stereomicroscope (Carl Zeiss ZEISS Stemi 2000C, Germany) was used to observe shell and operculum morphology for each specimen included in the study. A digital vernier (accurate to 0.1 mm) was used for shell measurements. Shells were photographed using SX520 HS Canon digital single-lens reflex camera. For SEM imaging, radulae were mounted on carbon conducting tape and sputter coated with Au-Pd. The scanning electron microscope (SEM) images of radulae were

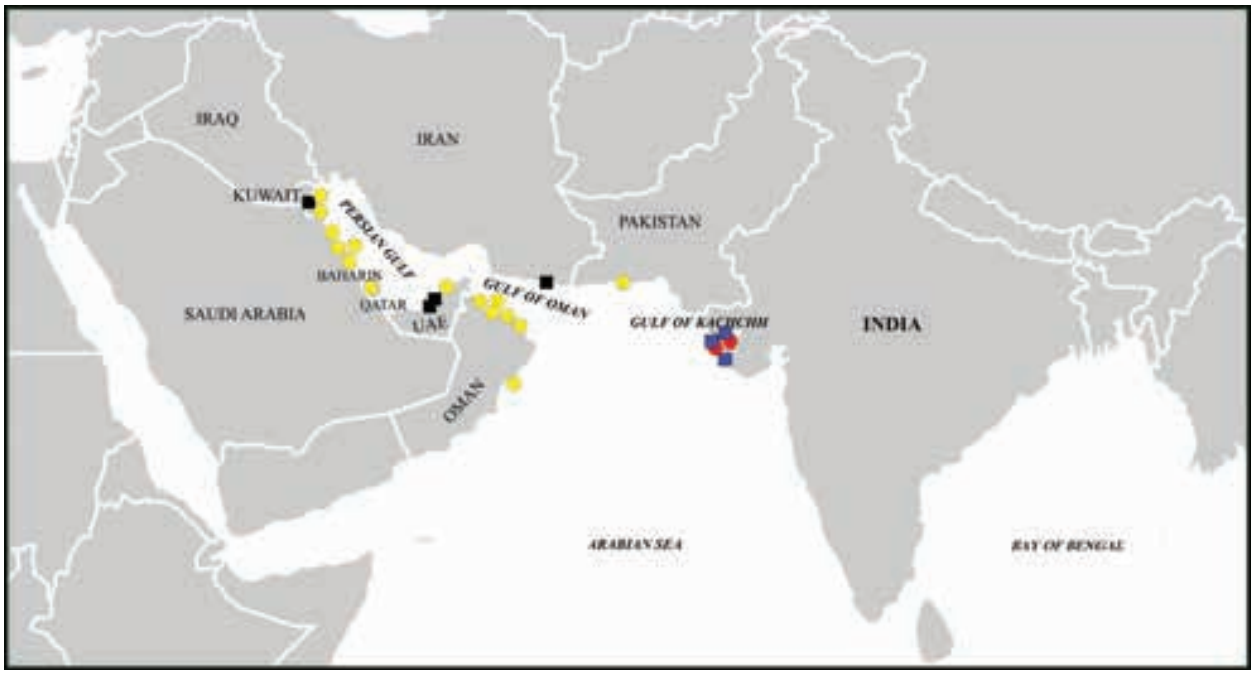

Figure 1. Geographical distribution of *Nassarius persicus* and *Nassarius tadjallii*. Symbols indicate following: Change the colour Yellow (●), known localities of *Nassarius persicus*; Red dot (●), its new localities from India. Black squares (¾), known localities of *Nassarius tadjallii;* blue squares (¾), its new localities from India.

obtained on JEOL JSM 6360A (JEOL, Japan) operating at 10 kV. The materials were confirmed following descriptions provided by Cernohorsky (1984), Bosch et al. (1995), & Moolenbeek (2007) and species names are updated from the (WoRMS) website (Molluscabase Eds. 2021).

RESULTS

Systematics

Family Nassariidae Iredale, 1916 (1835)
Subfamily Nassariinae Iredale, 1916 (1835)
Genus *Nassarius* Duméril, 1805
Type species: *Buccinum arcularia* Linnaeus, 1758 (by subsequent monotypy; Froriep, 1806).

***Nassarius persicus* (Martens, 1874)**
(Images: 1A; 2A–B, E–G & I)
Vernacular name: Persian Nassa.
Type locality: Persian Gulf.

1874.	*Nassa persica* v. Martens, Novit. Conch. Suppl. 5: 94, pl. 5, fig. 47.
1984.	*Nassarius (Plicarcularia) persicus* (v. Martens, 1874) —Cernohorsky, Bull. Auckland. Inst. Mus. 14: p. 71, pl. 5, figs. 3–6.
2008.	*Nassarius arcularia plicatus* (Röding, 1798) —Ghosh: pl. 1, figs 5–6.
2008.	*Nassarius olivaceus* (Bruguière, 1789) —Dave & Mankodi: fig. 1.

Examined material: Holotype: Catalogue number 69524 (specimen in Zoological Museum, Humboldt University, Berlin) (image examined from Cernohorsky, 1984: pl. 5, Image 2).

Other material: BNHS NASSA 303, 1 ex., adult, 1.iv.2014, Poshitra, Devbhumi Dwarka, Gujarat, India, 22.403N, 69.201E, coll. Deepak Apte, shell length 21.0 mm, shell width 13.1 mm. BNHS NASSA 304 (Figs. 2A-B), 1 ex., adult, 1.iv.2014, Poshitra, Devbhumi Dwarka, Gujarat, India, 22.403N, 69.201E, coll. Deepak Apte, shell height 21.6 mm, shell width 13.5 mm. BNHS NASSA 305, 1 ex., adult, 1.iv.2014, Poshitra, Devbhumi Dwarka, Gujarat, India, 22°24'12.9"N, 69°12'05.8"E , coll. Deepak Apte, shell height 23.0 mm, shell width 14.4 mm. BNHS NASSA 325, 1 ex., adult, 15.i.2015, Narara, Devbhumi Dwarka, Gujarat, India, 22.469N, 69.722E, coll. Sayali Nerurkar, shell height 22.3 mm, shell width 13.3 mm. BNHS NASSA 326, 1 ex., adult, 15.i.2015, Narara, Devbhumi Dwarka, Gujarat, India, 22.469N, 69.722E, coll. Sayali Nerurkar, shell height 22.2 mm, shell width 14.3 mm. BNHS NASSA 304 was used for dissecting radula and studying other morphological characters.

Diagnosis

Shell: Shell up to 23 mm in length (20.8 mm in holotype), elongate-ovate, with high, conical spire (Figs. 2A–B); very thin periostracum clearly visible in the live animal. Protoconch of three glassy-white whorls (Figs. 2E–F). Teleoconch of 6.5–7.25 weakly convex whorls, sculptured with strong axial ribs. Axial ribs are angulate and weakly constricted by a sharp, subsutural spiral line, to form weak nodes at the suture (same as that of holotype); ribs numbering from 12–14 on the penultimate and 12–19 on the body whorl, ribs becoming moderately obsolete in the center of the body whorl; only body whorl sculptured with very weak spiral striae, 3–4 basal spiral threads more prominent, siphonal fasciole with cords. Colour of shell is yellowish to olive green in live animals while dry shells look straw-yellow or pale grey. A creamy, pale colored spiral band is clearly visible on the shell with a nebulous darker band in the background of dorsal side of body whorl. The body whorl ends with four to five shallow axial ribs followed by a strong varix. Colour of varix is same as that of the shell. Aperture white, ovate, narrow, with 3 brown bands interiorly; outer lip thickened, edge slightly turned backwards; interior of outer lip with 7–8 lirate denticles (same as that of holotype). Columella heavily calloused, white, columellar shield large and extending up to body whorl suture; columella plicate with one strong plication at the base and 5–8 small folds. Anterior or siphonal canal short, distinct, wide and marked with 4–5 oblique basal cords. Posterior or anal canal distinct, deep, "U" shaped and marked by an intense posterior columellar ridge.

Operculum (Image 2G): Operculum corneous, yellowish to light brown in colour, serrate at the margins. Roughly trapezoidal in shape with curved bases, simple, flattened with terminal basal nucleus which is slightly turned to left. Information on operculum of holotype is not available.

Radula (Image 2K): Approximately, 62–70 rows of teeth, rachidian teeth with concave crescentic base, cutting edge is fringed with 11 or 12 sharp pointed, conical denticles with symmetrical arrangement. Corners of rachidian plate wide and smooth. Accessory intermediate lateral plates present in between each rachidian tooth and left lateral and right lateral tooth, respectively. Lateral teeth with two arched, narrow, elongated and pointed hook-like cusps, basal cusp is shorter than the upper cusp; the inner cutting edge of the basal cusp (between the two cusps) is finely serrate. The outer edge of the basal cusp (below the basal spur) is serrate with small five to six sharp, pointed denticles.

Image 1. A—Dorsal view of living animal of *Nassarius persicus* (Martens, 1874) from Poshitra, Gujarat, India, BNHS NASSA 304 | B—Dorsal view of living animal of *N. tadjallii* Moolenbeek, 2007 from Shivrajpur, Gujarat, India, BNHS NASSA 340. © Deepak Apte.

Basal spur is somewhat flat with a small bump.

Distribution (Figure 1): Saudi Arabia, Persian Gulf: Al Khobar; Ain-as-saih near Al Khobar; Ras Mishab; Tarut Bay; Saihat; Dammam. Bahrain: Al Manamah; Zallaq, Sheiks beach. KUWAIT: Failakah I.; Injifa shore; Kuwait Bay. United Arab Emirates: Trucial Coast, Sharjah. Oman: Mina al Fahal; Masirah I.; 18 km south-east of Muscat (mangrove/muddy flats); Marsis, Masirah I.; 2 km north of Sur Masirah, Masirah I.; Sur Masirah beach, Masirah I.; Dawwah beach, Masirah I.; southeastern end of Bar Al Hikman Peninsula; Al Sawadi Resort, Muscat; Muscat; As Seeb, 3 miles offshore (40 m depth); Bandar Jissah. Pakistan: Karachi. (GBIF Occurrences https://www.gbif.org/species/10492859; Cernohorsky 1984; Bosch et al. 1995; DuPont & Al-Tamimi 2002; Feulner & Hornby 2006; Al-Yamani et al. 2012; Asgari et al. 2012; El-Sorogy 2016; Grizzle et al. 2018; Al-Kandari et al. 2020; Yekta & Dekker 2021).

Localities within India: Previously none.

New localities within India (Figure 1): Narara and Poshitra, both localities in the Gulf of Kachchh, district Devbhumi Dwarka, Gujarat.

Habitat: Intertidal, up to 1 m depth, within degraded reef-flat with coral sand and silt.

Remarks: *Nassarius persicus* occur abundantly in its habitat and observed to be a dominant member of the intertidal fauna in intertidal reef-flats of Poshitra, Gujarat. It is a new record for India and a valuable addition to the fauna of Gulf of Kachchh Marine Sanctuary, Gujarat. Formerly, this species was misidentified (Ghosh 2008; Dave & Mankodi 2008), but a thorough investigation of its morphological characters clarifies its correct identity. The shell of *N. persicus* is similar to the western Indian Ocean species *N. arcularia plicatus* (Röding, 1798) in having large shield like columellar callous extending up to the penultimate whorl, creamy-yellow to pale grey colour of shells, a narrow brown band or dark brown spots or a nebulous darker band between sutural coronations of shells of both the species. But *N. persicus* can be easily distinguished from *N. arcularia plicatus* in having a slender shell with high spire, *N. arcularia plicatus* has a globous shell with moderate spire and spiral sculpture. Misidentification of *N. persicus* as *N. olivaceus* could be only due to the 'olive green' colour of the shell in live condition, else not any morphological similarity exists between these two species.

***Nassarius tadjallii* Moolenbeek, 2007**
(Images 1B; 2C–D, H–J & L)
Vernacular name: Tadjalli's Nassa.

2007.	*Nassarius tadjallii* Moolenbeek: 94, pl. 5, fig. 47.

Type locality: Ras al Batin, Abu Dhabi, United Arab Emirates.

Examined material: Holotype: ZMA.MOLL.139465, adult, i.1997, Ras al Batin, Abu Dhabi, United Arab Emirates, in breakwaters, 3m, coll. P. Micali (images examined from Moolenbeek, 2007: p. 58, figs. 1, 2) (specimen in Naturalis Biodiversity Center, Leiden, Netherlands). NMR56145, 1 ex., adult, Al Bide, Kuwait, in sand at low tide, 14.iv.1982, coll. J.G.B. Nieuwenhuis (image examined from https://www.nmr-pics.nl/Nassariidae_new/album/slides/Nassarius%20marmoreus.html (specimen in the Natural History Museum, Rotterdam).

Other material: BNHS NASSA 323, 1 ex., adult, 15.i.2015, Narara, Devbhumi Dwarka, Gujarat, India, 22.469N, 69.722E, coll. Sayali Nerurkar, shell length 24.4 mm, shell width 12.2 mm. BNHS NASSA 324 (Figs. 2C–D), 1 ex., adult, 15.i.2015, Narara, Devbhumi Dwarka, Gujarat, India, 22.469N, 69.722E, coll. Sayali Nerurkar, shell length 24.0 mm, shell width 13.0 mm. BNHS NASSA 340 (Image 1B), 1 ex., adult, 17.i.2015, Shivrajpur, Devbhumi Dwarka, Gujarat, India, 22.345N, 68.949E,

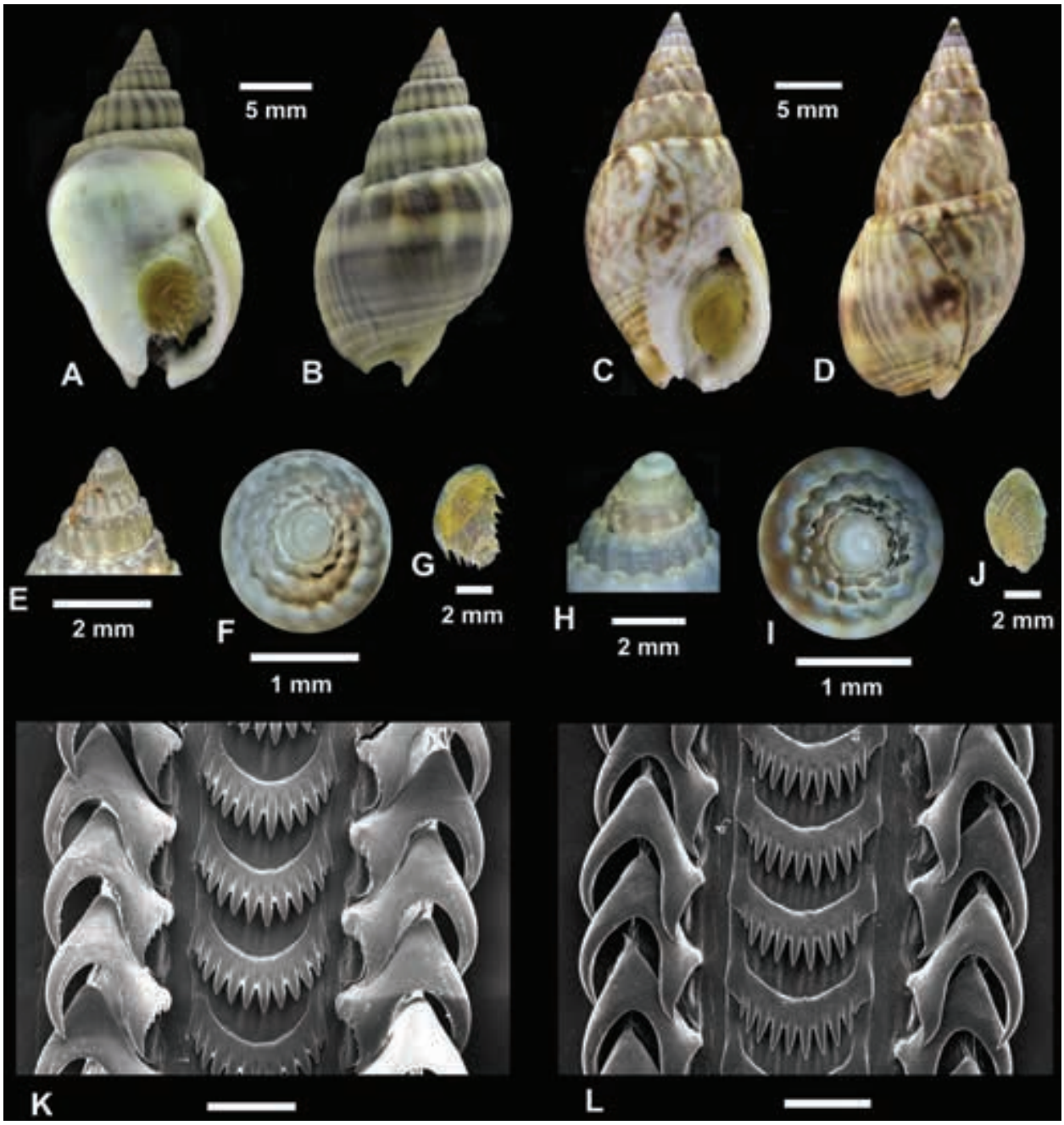

Image 2. ***Nassarius persicus*** **(Martens, 1874), BNHS NASSA 304. A–B—Shell, height 21.6mm, width 13.5mm | E–F—apex | G—operculum | K—radula (scale= 100µm).** ***Nassarius tadjallii*** **Moolenbeek, 2007, BNHS NASSA 324: A-B—Shell | C-D—Shell, height 24.0mm, width 13.0mm | H-I—apex | J—operculum | L—radula (scale= 100µm). © Sayali Nerurkar.**

coll. Deepak Apte, shell height 26.4 mm, shell width 13.9 mm. BNHS NASSA 348, 1 ex., adult, 18.i.2015, Poshitra, Devbhumi Dwarka, Gujarat, India, 22.403N, 69.201E, coll. Deepak Apte, shell height 28.4 mm, shell width 14.2 mm. BNHS NASSA 324 was used for dissecting the radula and studying other morphological characters.

Diagnosis

Shell: Shell up to 28.4 mm in length (25.4 mm in holotype), elongate-ovate, conical with high spire and less convex whorls (Figs. 2C–D); periostracum was thin, fibrous, brownish (thin, fibrous, brownish periostracum present in holotype). Protoconch of 2.5 white whorls approximately (Figs. 2H–I). Teleoconch of 6.25 to 6.50 whorls, of which first three axially ribbed and with 4–6

spiral grooves gradually disappearing; remaining whorls smooth with only one, rather strong sub-sutural groove. Suture prominently channeled. Between the suture and the sub-sutural groove, the area is slightly nodulose and consists of alternate creamy white and dark brown dots. Shell colour is white or cream in the background with light and dark brown patterned patches. These patches are arranged in two light and three dark alternate bands, visible on the body whorl (shell colour in holotype is light brown, with darker brown patches). This banding pattern is not mentioned in the original description. The body whorl ends with three to four minor axial ridges followed by a strong varix. Varix is creamy white in colour and bears three distinct brown patches as extensions of the three dark patterned bands of the body whorl (Varix orange brown in holotype. This brownish hue caused by its intact periostracum). Aperture whitish, ovate, moderately wide, interior of outer lip with about nine lirate denticles. Columella plicate with two or three fine folds. Columellar callus thin, smooth, white, spreading slightly on body whorl and extending outwards at siphonal canal forming anterior ridge. Anterior or siphonal canal short, distinct, wide and marked with five spiral grooves or basal cords which ends as five denticles on outer lip. Posterior or anal canal distinct, moderately deep and marked by a strong posterior columellar ridge and a strong denticle on the top of the outer lip. Parietal denticle also prominent. Shell of BNHS NASSA 324 has three to four prominent repair scars on penultimate and body whorls.

Operculum (Image 2J): Operculum of BNHS NASSA 324 is corneous, yellowish brown in colour. Trapezoidal, elongate, simple, flattened with smooth inner margin, crenate outer margin and terminal nucleus. Information on operculum of holotype is not available.

Radula (Image 2L): Radula consists of 62–68 rows of teeth; rachidian teeth with concave crescentic base and cutting edge fringed with 9–11 sharp, pointed, conical denticles in symmetrical arrangement; corners of rachidian plate wide and smooth; accessory intermediate lateral plates present in between each rachidian tooth and left lateral and right lateral tooth, respectively. Lateral teeth with two arched, narrow, elongated and pointed hook-like cusps, the basal cusp being shorter than the upper cusp; the inner cutting edge of the lateral teeth (between the two cusps) is smooth. The outer edge of the basal cusp (below the basal spur) is also smooth. Basal spur is prominent. Information on radula of holotype is not available.

Distribution (Figure 1): United Arab Emirates: Ras al Batin, Abu Dhabi; Al Imarat, Abu Dhabi; Dubai. Kuwait: Al Bide; Bede Circle; Kuwait Towers; Kuwait Bay. Iran: Chahbahar. Oman: not any specific locality given (GBIF Occurrences https://www.gbif.org/species/6502821; Moolenbeek 2007; Al-Yamani et al. 2012; Al-Kandari et al. 2020; Yekta & Dekker 2021).

Localities within India: Previously none.

New localities within India (Figure 1): All three localities namely, Narara, Poshitra from Gulf of Kachchh and Shivrajpur (Arabian Sea), falls under district Devbhumi Dwarka, Gujarat, on northwestern coast of India.

Habitat: Intertidal, up to 1 m depth, within degraded reef-flat with coral sand and silt.

Remarks: *Nassarius tadjallii* Moolenbeek, 2007 is a new record for India which extends the distribution eastwards and is an addition to the marine fauna of Gujarat. This species shows morphological similarities and can be confused with *N. marmoreus* (A. Adams, 1852), *N. javanus* (Schepman, 1891) and *N. thachorum* Dekker et al., 2016. *N. marmoreus* from Oman is smaller and much darker in colour compared to *N. tadjallii*. *N. javanus*, which can be found in India (Tamil Nadu), is smaller and has a much more globose body whorl. *N. thachorum* from Vietnam differs from *N. tadjallii* in having a much weaker or lacking subsutural groove, the presence of a ridge consisting of small denticles on the columella, and has a darker colour of the shell (Dekker et al. 2016).

DISCUSSION

Prior to this work, *Nassarius persicus* and *N. tadjalli* had not been reported from India (Nerurkar et al. 2020) and thus, the present records extend the known range of these species from the Arabian Peninsula to Gujarat, India. Both these species of *Nassarius* currently are found only at Narara, Poshitra (Gulf of Katchchh) and Shivrajpur (Arabian Sea but close to Gulf of Katchchh) and not seen along the rest of the Indian coasts.

Marine fauna changes considerably in the northern part of the Gujarat State, especially in the Gulf of Katchchh. In the north, the fauna is influenced by the Arabian Sea upwelling which appears to have significant influence on the faunal change from Gulf of Katchchh across Mekran and into the Arabian Gulf. But we know little about it as faunal barrier. Williams et al. (2011) while discussing continental ark idea, observed a similar pattern in the case of dispersal of *Lunella coronata* (Gmelin, 1791) morph B along the continental coastline, from Arabian Peninsula to Porbunder, Gujarat, India.

Likewise, Tripathy et al. (2013) listed *Congetia chesneyi* (Oliver & Chesneyi, 1994) from Adatara from the Gulf of Katchchh , Gujarat, India which otherwise in is known only from Kuwait area.

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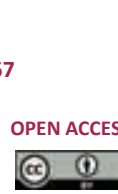

COMMUNICATION

Flowering plants of Agumbe region, central Western Ghats, Karnataka, India

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Abstract: Agumbe, the Cherrapunji of southern India, is a bastion of rich endemic flora. In the present study of random sampling, a total of 570 species of flowering plants were collected belonging to 370 genera and 105 families, including a few endemic and Red Listed medicinal plants such as *Garcinia gummi-gutta* (L.) Roxb., *Dipterocarpus indicus* Bedd., *Dysoxylum malabaricum* Bedd. ex C.DC., *Elaeocarpus tuberculatus* Roxb., *Hopea canarensis* Hole, *Calophyllum apetalum* Willd., *Adenia hondala* (Gaertn.) W.J.de Wilde, and *Myristica dactyloides* Gaertn. Family Leguminosae contributes the maximum number of species (47 species) followed by Rubiaceae (32 species) and Asteraceae (27 species) and Genera *Ficus* (9 species), *Diospyros* (8 species) and *Syzygium* (7 species) are the dominant genera. Trees (185 species) are the dominant species followed by herbs (162 species), climbers (117 species), shrubs (62 species), grasses and sedges (19 species), epiphytes (15 species) and parasites (10 species).

Keywords: *Dipterocarpus*, endemic, Red Listed medicinal plants.

Editor: Anonymity requested.

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Competing interests: The authors declare no competing interests.

Author details: G.S. Adithya Rao is very much Interested in Plant taxonomy and diversity assessment. Presently working in Karnataka Forest Department as Deputy Range Forest Officer cum Surveyor and working for compiling the Flora of Shivamogga District. Y.L. Krishnamurthy is Professor in Applied Botany and he has expert in Plant Biodiversity - survey, documentation and conservation and fungal endophytes - Enhancement of plant growth by incorporation of beneficial fungi and fungal metabolite profiling, Exploration and characterization of lichens.

Author contributions: GSA - carried out the field work, data collection, identification, photography, data interpretation, manuscript writing. YLK - carried out the field work, guided for data interpretation and manuscript writing.

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INTRODUCTION

Taxonomic studies and floristic explorations can provide efficient and convenient information regarding the nomenclature, distribution and ecology, utility of various plants species, and about an ecosystem. It is estimated that the tropical forests harbor about 70% of living organisms of the whole world, of which roughly 20% of the total are confined as exclusively endemic throughout the tropical forests (Myers 1988).

India is one among 18 mega biodiversity nations harboring about 4,381endemic species of flowering plants (Nayar, 1996; Shigwan et al. 2000; Singh et al. 2015). Among 35 global biodiversity hot spots (Mittermeier et al. 2011) identified, India has four; including the Western Ghats, which is the second largest endemic centers in India with 1,273 species (Nayar et al. 2014 a,b).

The Western Ghats is one of the two high diversity humid tropical forest tracks in India. The most outstanding feature of the Western Ghats is the formation of tropical rain forests along the windward side facing the Arabian Sea. The tropical climate complimented by heavy precipitation from the south-west monsoon and favorable edaphic factors create an ideal condition for the luxuriant growth of plant life, which can be seen only in a few parts of the world (Gadgil 1996). The tropical forests have received much attention in recent years because of their species richness, high standing biomass, and greater productivity (Denslow 1987). A rainforest is a dense, wet, and tropical evergreen ecosystem, high in its level of biodiversity. One among the tropical rainforests of the Western Ghats is found in the Agumbe region.

According to the Karnataka State Natural Disaster Monitoring Centre (KSNDMC), Hulikal (442m), located more than 244m below Agumbe (686m) area, has received heavy rainfall (more than 125mm) on an average of 4.6 times a year compared to twice a year in Agumbe during the past decade. The reason for the variation of rainfall in Hulikal is the construction of a reservoir, which has created an anthropogenic impact on the environment and the weather system and that has led to heavy rainfall. There has been a change in the temperature, humidity and soil moisture in Hulikal after the construction of the dam (Prabhu 2011).

Agumbe, the Cherrapunji of the south is famous for its endemic flora and medicinal plants (Sundararaghavan 1970). Hence, the present study was conducted with the intention to report the present status of the flowering plant diversity of this region, as there is no updated account available for this ecologically unique and important region.

MATERIALS AND METHODS

Study area

The study area is 568ha of tropical low-land evergreen forest of Agumbe (13.5087°N 75.0959°E) in Shivamogga district of Karnataka, India. Agumbe tropical rain forests are the heart of central Western Ghats with a wide range of species composition and floral distribution. These forests are classified as tropical wet evergreen forests of the *Dipterocarpus indicus-Humboldtia brunonis-Poeciloneuron indicum* type (Pascal 1988). The mean annual rainfall is 7,620mm (300 inches) and the average temperatures vary between 22.2°C and 23.6°C with an annual average temperature of 23.5°C. Agumbe lies in a hilly, wet region of the Western Ghats with an elevation of 643m (2,250ft), canopy cover of 80–85% and lies in a UNESCO World Heritage Site (UNESCO 2011). According to Champion & Seth's (1968) classification, Agumbe is an area of "southern tropical wet evergreen forests". The Agumbe Medicinal Plants Conservation Area (MPCA) was established in 1999 to protect the important medicinal plants of the region (Figure 1).

Methods

This study was carried out in all the climatic seasons covering Agumbe and Kundadri MPCA, Agumbe Reserve Forest and a few parts of Someshwara Wildlife Sanctuary between 2016 and 2018. The survey was conducted using random sampling methods (Cochran 1977). Plant specimens were collected and identified by using available regional floras (Saldanha & Nicolson 1976; Yoganarasimhan et al. 1981; Saldanha 1984; Gamble 1998; Ramaswamy et al. 2001; Punekar & Lakshminarasimhan 2011; Bhat 2014). Names and families of the plants were updated using The Plant List (www.theplantlist.org) and Herbarium JCB (Rao et al. 2012 (http://florakarnataka.ces.iisc.ac.in/hjcb2)). The herbarium specimens were deposited in the Herbarium, Department of Applied Botany, Kuvempu University, Shivamogga, Karnataka.

RESULTS

A total of 570 species of flowering plants belonging to 370 genera and 105 families occur in the present study area. Among all the flowering plants, trees (185

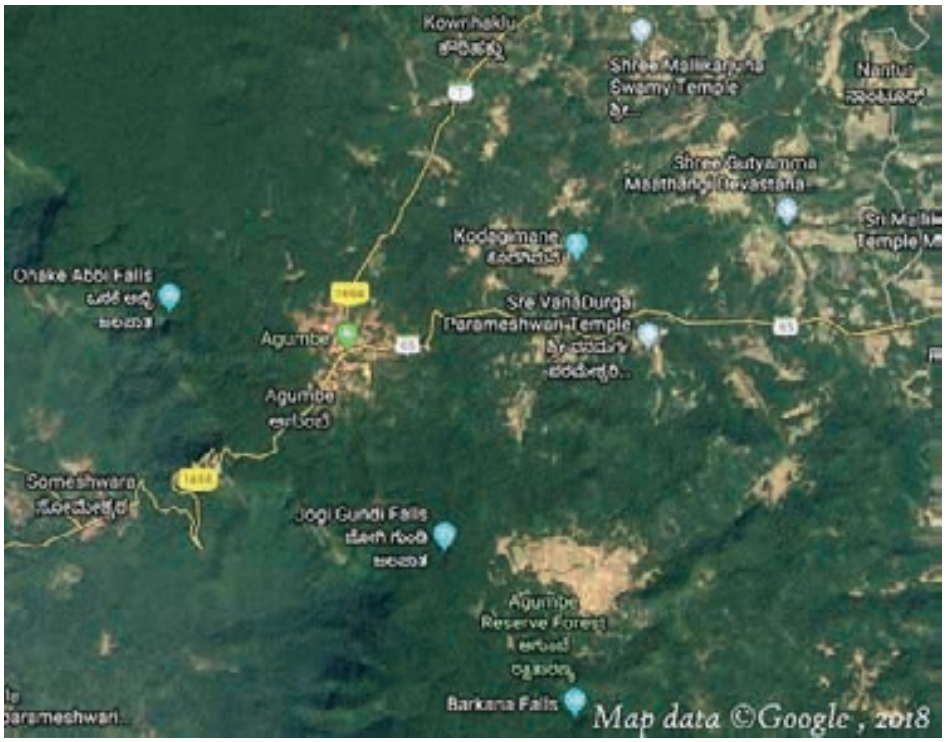

Figure 1. Agumbe region, central Western Ghats.

species) contribute the maximum number followed by herbs (162 species), climbers (117 species), shrubs (62 species), grasses & sedges (19 species), epiphytes (15 species), and parasites (10 species) (Figure 2, Image 1–24). Family Leguminosae (47 species) contributes the maximum number of species followed by Rubiaceae (32 species), Asteraceae (27 species), Acanthaceae (28 species), Apocynaceae (22 species) and so on.

Genus *Ficus* L., contributing 9 species followed by *Diospyros* L. with eight species, *Syzygium* R.Br. ex Gaertn. with seven species, *Impatiens* L., *Solanum* L. with six species each. *Acacia* Mart., *Blumea* DC., *Dendrobium* Sw., *Garcinia* L., *Phyllanthus* L. *Terminalia* L. and *Senna* Mill., with five species each (Figure 3).

Agumbe is the home for numerous endemic plants to the Western Ghats such as *Acronychia pedunculata* (L.) Miq, *Calophyllum apetalum* Willd., *Dipterocarpus indicus* Bedd., *Dysoxylum malabaricum* Bedd. ex C.DC., *Embelia ribes* Burm.f., *Hopea canarensis* Hole, *Garcinia gummi-gutta* (L.) Roxb., *Myristica dactyloides* Gaertn., *Persea macrantha* (Nees) Kosterm., *Syzygium gardneri* Thwaites, and many were conserved in the reserve forests (RF), Someshwara Wildlife Sanctuary (SWS), and MPCAs.

Among 185 trees, Leguminosae (45 species), Moraceae (11 species), and Lauraceae (10 species) members were dominant. Distribution wise the members of Dipterocarpaceae, Leguminosae, Ebenaceae and Moraceae were frequent and wide spread and *Arenga wightii, Elaeocarpus tuberculatus, Garcinia gummi-gutta, Knema attenuata, Myristica malabarica, Persea macrantha, Poeciloneuron indicum*, and *Syzygium gardneri* were commonly found in the Agumbe rainforests.

The study revealed the presence of 162 herbaceous species, in which 160 were ground flora. Among them Asteraceae emerged as the dominant family with 27 species followed by Acanthaceae (19 species), Poaceae (17 species), Lamiaceae (11 species), and Leguminosae (11 species). Many of the herbs were used for various medicinal and edible purposes. Some rarely seen plants like *Epipogium roseum,* a saprophytic land orchid, shows its emergence for only 15 days in a year with beautiful flowers, but vegetative phases are not seen on the ground.

Due to the dense canopy, only a few numbers of shrubs were observed during the present study. A total of 62 shrubs belonging to 25 families and 52 genera were observed. Among them, Rubiaceae and Acanthaceae emerged as dominant families with 10 and seven individuals, respectively. Species like *Ardisia solanacea, Atalantia monophylla* (respiratory disorders), *Gnidia glauca* (mumps), *Ixora coccinea* (fever), *Memecylon malabaricum* (herpes), *Pavetta*

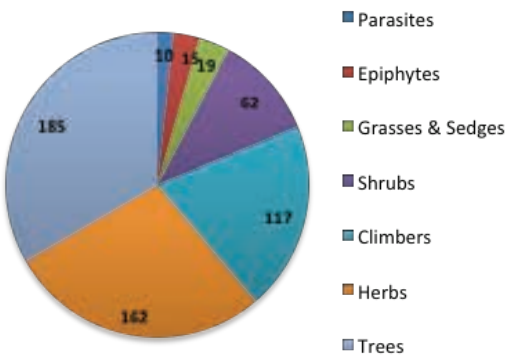

Figure 2. Habit-wise distribution of flowering plants of Agumbe region

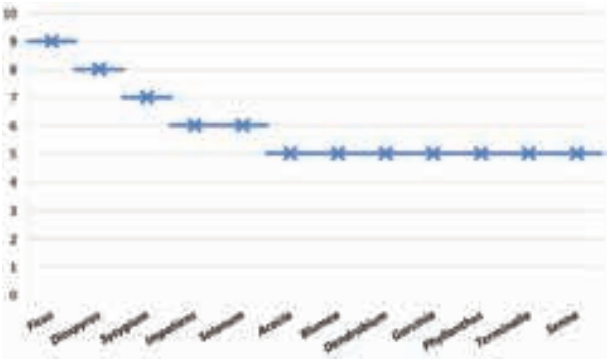

Figure 3. Graph showing dominant genera of the study area

crassicaulis (wounds), and *Thottea siliquosa* (dysentry) have medicinal importance (Udaya 2003). Evergreen forests are also rich in diversity of climbers and the study revealed the presence of a greater diversity of climbers with 117 species belonging to 42 families. Among these Apocynaceae (14), Leguminosae (13), and Convolulaceae (09) were dominant. Most of the climbers occurred in the study area having medicinal value and *Marsdenia raziana, Adenia hondala*, and *Salacia malabarica* are listed under Red Listed plants (IUCN 2017). Only 15 species of epiphytes were found in the study area. The majority of the epiphytes belong to Orchidaceae (12), followed by Apocynaceae, Gentianaceae, Gesneriaceae, and Moraceae with one species each,

A total of 10 angiospermic parasites were observed and they were seen on varied host plants such as *Terminalia paniculata, Terminalia tomentosa, Olea dioica*, and *Artocarpus hirsutus*. Family Loranthaceae with eight species emerged as the dominant family, followed by Convolvulaceae and Santalaceae with one species each (Annexure 1).

Among 570 flowering plants, 58 were considered threatened. Some species which are endangered need to be conserved for the future. These threatened species fall under 34 families, where Leguminosae and Dipterocarpaceae have five species each, followed by Lauraceae with four species and are the dominant families (https://www.iucnredlist.org) (Annexure 2).

DISCUSSION

A comparative analysis of tree diversity in the tropical lowland evergreen forests of Agumbe in three one hectare plots displayed the presence of 3,202 live stems representing 125 species of trees in 92 genera and 42 families (Srinivas & Parthasarathy 2000), whereas in the current study, 195 species of trees belonging to 54 families and 137 genera were observed in all the areas of the rain forests of Agumbe.

Species diversity and density of all woody climbers (lianas) inventoried in three one-hectare plots in the tropical lowland evergreen forest of Agumbe yielded a total of 1,138 lianas belonging to 40 species (Padaki & Parthasarathy 2000). In the current study, a total of 117 species of climbers were found to occur, of which 59 species were lianas.

A floristic survey carried out in Agumbe MPCA by the FRLHT botanical team reported 371 plant species of which 182 are medicinal. *Adenia hondala, Celastrus paniculatus, Garcinia gummi-gutta, Myristica dactyloides, Persia macrantha,* and *Vateria indica* are a few threatened species recorded from this area (Nayar & Sastry 1990). The study also revealed the Agumbe MPCA is a genuine storehouse of floristic diversity. The presence of pure stands of *Poeciloneuron indicum* is a significant character of this forest (Udayan 2003). But, in the current study the whole area of Agumbe rainforest was enumerated and yielded more momentous results than the other studies.

Bhat (2014) explored the floristic wealth of Dakshina Kannada district, observed 1,888 species of flowering plants belonging to 928 genera and 166 families and classified plants according to Angiosperm Phylogeny Group (APG) III. Among 1,273 species of flowering plants endemic to the Western Ghats (Nayar et al. 2014a,b), 195 species and five infra-specific categories occur in the surrounding areas of Dakshina Kannada and Udupi districts. Whereas in our study, we observed 570 flowering plants belonging to 370 genera and 105 families and we classified plants according to APG IV system of classification. The present study revealed the presence of 84 endemic species and 58 threatened plants distributed in the Agumbe region.

Major threats that are intimidating the diversity

and distribution of flowering plants in Agumbe are the illegal collection of non-timber forest products (NTFP) such as: fruits of *Garcinia gummi-gutta, G. indica, G. xanthochymus, Elaeocarpus tuberculatus, Diospyros* spp.*, Phyllanthus emblica, Myristica dactyloides, M. malabarica, Syzygium* spp., *Ficus racemosa*, and *Strychnos nux-vomica*; leaves and bark of *Cinnamomum verum, Alstonia scholaris, Saraca asoca* and many other species for their therapeutic and marketing value. Even though the forest department is undertaking many conservation efforts, many threatened and endemic plants need more specific conservation plans.

Very few pockets in the Western Ghats have a combination of high rainfall and luxuriant evergreen forests as do the Ghats forests of Agumbe. Some rarely seen plants like *Epipogium roseum,* a saprophytic land orchid and *Marsdenia raziana, Adenia hondala*, and *Salacia malabarica* which are listed as threatened were seen in the present study. Many of the herbs, shrubs, climbers, and trees are used for various medicinal and edible purposes. Medicinal plants and other endemic plants available in the Agumbe region are conserved in the Agumbe and Kundadri MPCAs, Agumbe Reserve Forest and some parts of the Someshwara Wildlife Sanctuary. All these rare plants should be given top priority for their conservation.

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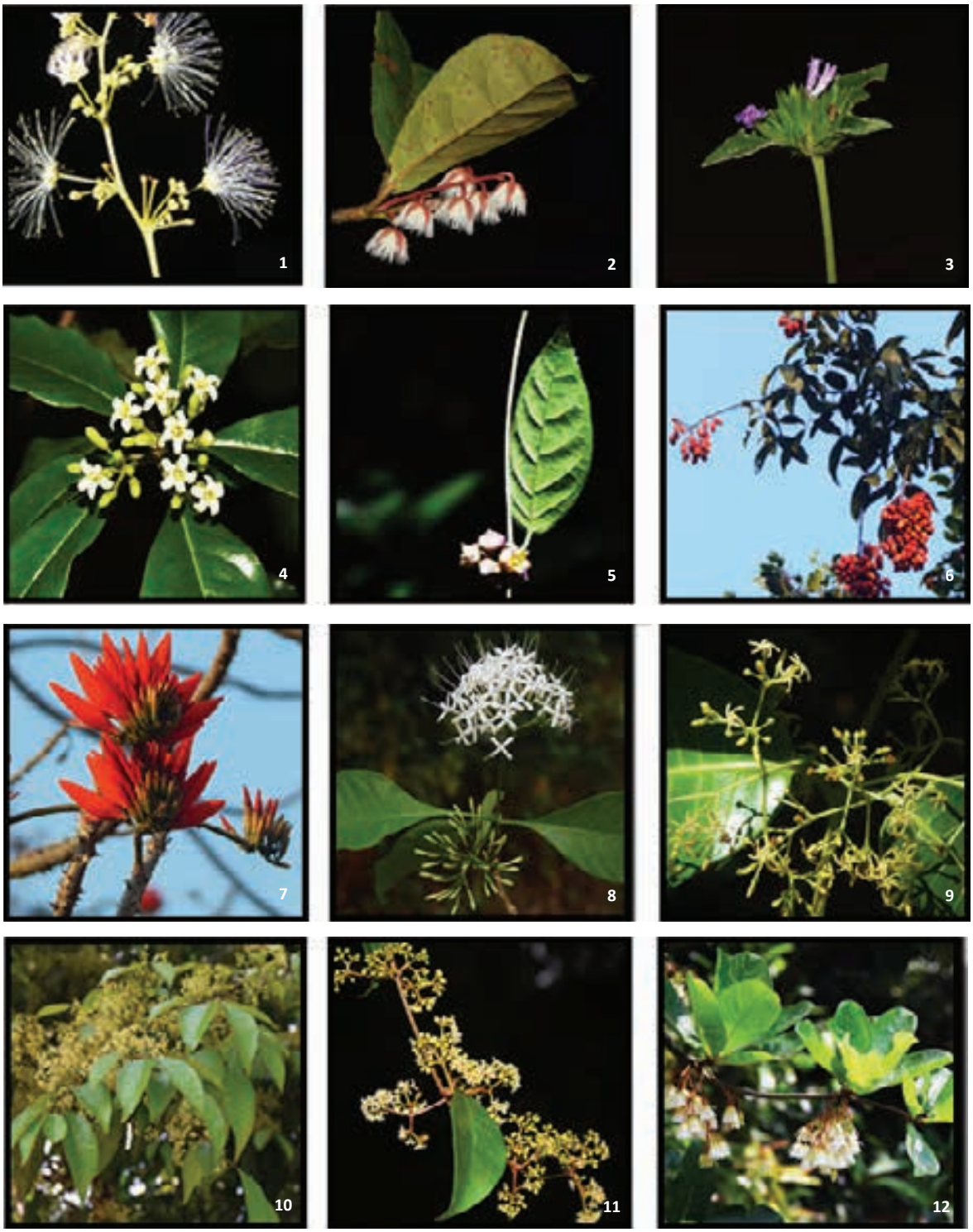

Image 1–12. 1—*Archidendron bigemium* | 2—*Elaeocarpus serratus* | 3—*Elephantopus scaber* | 4—*Pittosporum dasycaulon* | 5—*Marsdenia raiana* | 6—*Connarus wightii* | 7—*Erythrina suberosa* | 8—*Pavetta crassicaulis* | 9—*Anodendron paniculatum* | 10—*Olea dioica* | 11—*Genianthus laurifolius* | 12—*Elaeocarpus tuberculatus*. © G.S. Adithya Rao.

Image 13–24. 13—*Hemidesmus indicus* | 14—*Garcinia morella* | 15—*Adenia hondala* | 16—*Antidesma montanum* | 17—*Ardisia solanacea* | 18—*Bauhinia phoenica* | 19—*Dendrobium barbatulum* | 20—*Casearia tomentosa* | 21—*Erycibe paniculata* | 22—*Flemingia strobilifera* | 23—*Salacia malabarica* | 24—*Hoya wightii*. © G.S. Adithya Rao.

Annexure 1. Flowering plants enumerated in Agumbe region of central Western Ghats, Karnataka.

	Botanical name	Family	Habit
1	*Acacia auriculiformis* Benth. *	Leguminosae	T
2	*Acacia caesia* (L.) Willd.	Leguminosae	C
3	*Acacia mangium* Willd. *	Leguminosae	T
4	*Acacia pennata* (L.) Willd.	Leguminosae	C
5	*Acacia sinuata* (Lour.) Merr.	Leguminosae	C
6	*Acilepis ornata* (Talbot) H.Rob. & Skvarla	Asteraceae	H
7	*Acmella oleracea* (L.) R.K.Jansen *	Asteraceae	H
8	*Acmella radicans* (Jacq.) R.K.Jansen	Asteraceae	H
9	*Acmella uliginosa* (Sw.) Cass.	Asteraceae	H
10	*Acronychia pedunculata* (L.) Miq.	Rutaceae	T
11	*Actinodaphne hookeri* Meisn.	Lauraceae	T
12	*Actinodaphne wightiana* (Kuntze) Noltie	Lauraceae	T
13	*Adenia hondala* (Gaertn.) W.J.de Wilde	Passifloraceae	C
14	*Adenostemma lavenia* (L.) Kuntze	Asteraceae	H
15	*Aeginetia indica* L.	Orobancaceae	H
16	*Aerides maculosa* Lindl.	Orchidaceae	E
17	*Aeschynanthus perrottetii* A. DC.	Gesneriaceae	E
18	*Ageratum conyzoides* (L.) L.	Asteraceae	H
19	*Aglaia anamallayana* (Bedd.) Kosterm.	Meliaceae	T
20	*Aglaia elaeagnoidea* (A.Juss.) Benth.	Meliaceae	T
21	*Aglaia lawii* (Wight) C.J.Saldanha	Meliaceae	T
22	*Agrostistachys indica* Dalzell	Euphorbiaceae	S
23	*Ailanthus triphysa* (Dennst.) Alston	Simaroubaceae	T
24	*Albizia chinensis* (Osbeck) Merr. *	Leguminosae	T
25	*Albizia lebbeck* (L.) Benth.	Leguminosae	T
26	*Albizia odoratissima* (L.f.) Benth.	Leguminosae	T
27	*Albizia* saman (Jacq.) Merr. *	Leguminosae	T
28	*Allamanda cathartica* L .	Apocynaceae	C
29	*Allophylus cobbe* (L.) Raeusch.	Sapindaceae	C
30	*Alocasia macrorrhizos* (L.) G.Don	Araceae	H
31	*Alpinia galanga* (L.) Willd.	Zingiberaceae	H
32	*Alpinia malaccensis* (Burm.f.) Roscoe	Zingiberaceae	H
33	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	T
34	*Alternanthera ficoidea* (L.) Sm.	Amaranthaceae	H
35	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	H
36	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae	H
37	*Ampelocissus indica* (L.) Planch.	Vitaceae	C
38	*Anacardium occidentale L.* *	Anacardiaceae	T
39	*Ancistrocladus heyneanus* Wall. ex J.Graham	Ancistrocladaceae	C
40	*Anisomeles indica* (L.) Kuntze	Lamiaceae	H
41	*Anodendron paniculatum* A.DC.	Apocynaceae	C
42	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Bedd.	Combretaceae	T
43	*Antidesma montanum* Blume	Phyllanthaceae	T
44	*Antigonon leptopus* Hook. & Arn.	Polygonaceae	C
45	*Aporosa cardiosperma* (Gaertn.) Merr.	Phyllanthaceae	T
46	*Archidendron bigeminum* (L.) I.C.Nielsen	Leguminosae	T
47	*Ardisia paniculata* Roxb.	Primulaceae	S
48	*Ardisia solanacea* (Poir.) Roxb.	Primulaceae	S
49	*Arenga wightii* Griff.	Arecaceae	T
50	*Argyreia elliptica* Arn. ex Choisy	Convolvulaceae	C
51	*Argyreia nervosa* (Burm. f.) Bojer	Convolvulaceae	C
52	*Argyreia pilosa* Wight & Arn.	Convolvulaceae	C
53	*Argyreia populifolia* Choisy	Convolvulaceae	C
54	*Aristolochia ringens* Vahl	Aristolochiaceae	C
55	*Aristolochia tagala* Cham.	Aristolochiaceae	C
56	*Artabotrys zeylanicus* Hook.f. & Thomson	Annonaceae	C
57	*Artocarpus heterophyllus* Lam.	Moraceae	T
58	*Artocarpus hirsutus* Lam.	Moraceae	T
59	*Arundinella pumila* (Hochst.) Steud.	Poaceae	G
60	*Arundinella purpurea* Hochst. ex Steud.	Poaceae	G
61	*Asparagus gonoclados* Baker	Asparagaceae	C
62	*Asparagus racemosus* Willd.	Asparagaceae	C
63	*Atalantia monophylla* DC.	Rutaceae	S
64	*Bambusa bambos* (L.) Voss	Poaceae	G
65	*Bambusa vulgaris* Schrad. *	Poaceae	G
66	*Barringtonia racemosa* (L.) Spreng. *	Lecythidaceae	T
67	*Bauhinia phoenicea* Wight & Arn.	Leguminosae	C
68	*Bauhinia purpurea* L.	Leguminosae	T
69	*Begonia crenata* Dryand.	Begoniaceae	H
70	*Begonia malabarica* Lam.	Begoniaceae	H
71	*Beilschmiedia dalzellii* (Meisn.) Kosterm.	Lauraceae	T
72	*Biophytum sensitivum* (L.) DC.	Oxalidaceae	H
73	*Blachia andamanica* subsp. *denudata* (Benth.) N.P.Balakr. & Chakrab.	Euphorbiaceae	T
74	*Blumea axillaris* (Lam.) DC.	Asteraceae	H
75	*Blumea lacera* (Burm.f.) DC.	Asteraceae	H
76	*Blumea lanceolaria* (Roxb.) Druce	Asteraceae	H
77	*Blumea oxyodonta* DC.	Asteraceae	H
78	*Blumea virens* DC.	Asteraceae	H
79	*Boehmeria glomerulifera* Miq.	Urticaceae	S
80	*Bombax ceiba L.*	Malvaceae	T
81	*Breynia retusa* (Dennst.) Alston	Phyllanthaceae	S
82	*Breynia vitis-idaea* (Burm.f.) C.E.C.Fisch.	Phyllanthaceae	S

	Botanical name	Family	Habit
83	*Bridelia stipularis* (L.) Blume	Phyllanthaceae	C
84	*Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Bercht. & J.Presl	Solanaceae	S
85	*Bryophyllum* pinnatum (Lam.) Oken	Crassulaceae	H
86	*Buchanania cochinchinensis* (Lour.) M.R.Almeida	Anacardiaceae	T
87	*Bulbophyllum sterile* (Lam.) Suresh	Orchidaceae	E
88	*Butea monosperma* (Lam.) Taub.	Leguminosae	T
89	*Caesalpinia cucullata* Roxb.	Leguminosae	C
90	*Cajanus lineatus* (Wight & Arn.) Maesen	Leguminosae	S
91	*Calacanthus grandiflorus* (Dalzell) Radlk.	Acanthaceae	S
92	*Calamus dransfieldii* Renuka	Arecaceae	C
93	*Calamus thwaitesii* Becc.	Arecaceae	C
94	*Callicarpa tomentosa* (L.) L.	Lamiaceae	T
95	*Calophyllum apetalum* Willd.	Clusiaceae	T
96	*Calyptocarpus vialis* Less.	Asteraceae	H
97	*Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult.	Gentianaceae	H
98	*Canscora perfoliata* Lam.	Gentianaceae	H
99	*Canthium rheedei* DC.	Rubiaceae	C
100	*Capillipedium huegelii* (Hack.) A.Camus	Poaceae	G
101	*Capparis baducca* L.	Capparaceae	S
102	*Capparis moonii* Wight	Capparaceae	C
103	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	T
104	*Cardiospermum halicacabum* L.	Sapindaceae	C
105	*Careya arborea* Roxb.	Lecythidaceae	T
106	*Carissa spinarum* L.	Apocynaceae	C
107	*Cascabela thevetia* (L.) Lippold	Apocynaceae	S
108	*Casearia rubescens* Dalzell	Salicaceae	T
109	*Casearia tomentosa* Roxb.	Salicaceae	T
110	*Cassia fistula* L.	Leguminosae	T
111	*Cassine glauca (*Rottb.) Kuntze	Celastraceae	T
112	*Catharanthus roseus* (L.) G.Don	Apocynaceae	H
113	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	T
114	*Cayratia mollissima* (Planch.) Gagnep.	Vitaceae	C
115	*Cayratia trifolia* (L.) Domin	Vitaceae	C
116	*Celastrus paniculatus* Willd.	Celastraceae	C
117	*Celtis timorensis* Span.	Cannabaceae	T
118	*Centella asiatica* (L.) Urb.	Apiaceae	H
119	*Centipeda minima* (L.) A.Braun & Asch.	Asteraceae	H
120	*Centotheca lappacea* (L.) Desv.	Poaceae	H
121	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae	S
122	*Chionanthus mala-elengi* (Dennst.) P.S.Green	Oleaceae	T
123	*Chonemorpha fragrans* (Moon) Alston	Apocynaceae	C
124	*Chrysophyllum flexuosum* Mart.	Sapotaceae	T
125	*Chrysopogon aciculatus* (Retz.) Trin.	Poaceae	G
126	*Cinnamomum cassia* (L.) J.Presl	Lauraceae	T
127	*Cinnamomum malabatrum* (Burm.f.) J.Presl	Lauraceae	T
128	*Cinnamomum verum* J.Presl	Lauraceae	T
129	*Cissus glyptocarpa* Thwaites	Vitaceae	C
130	*Cissus javana* DC.	Vitaceae	C
131	*Clausena dentata* (Willd.) Roem.	Rutaceae	T
132	*Clematis gouriana* Roxb. ex DC.	Ranunculaceae	C
133	*Clerodendron infortunatum* Gearth	Lamiaceae	S
134	*Clerodendrum paniculatum* L.	Lamiaceae	S
135	*Clitoria ternatea* L.	Leguminosae	C
136	*Coelogyne breviscapa* Lindl.	Orchidaceae	E
137	*Colebrookea oppositifolia* Sm.	Lamiaceae	S
138	*Colocasia esculenta* (L.) Schott	Araceae	H
139	*Combretum indicum* (L.) DeFilipps *	Combretaceae	C
140	*Combretum latifolium* Blume	Combretaceae	C
141	*Commelina benghalensis* L.	Commelinaceae	H
142	*Connarus wightii* Hook.f.	Connaraceae	C
143	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae	H
144	*Crateva religiosa* G.Forst.	Capparaceae	T
145	*Crotalaria filipes* Benth.	Leguminosae	H
146	*Crotalaria pallida* Aiton	Leguminosae	H
147	*Crotalaria retusa* L.	Leguminosae	H
148	*Croton caudatus* Geiseler	Euphorbiaceae	C
149	*Croton gibsonianus* Nimmo	Euphorbiaceae	S
150	*Cryptocarya lawsonii* Gamble	Lauraceae	T
151	*Curculigo orchioides* Gaertn.	Hypoxidaceae	H
152	*Curcuma oligantha* Trimen	Zingiberaceae	H
153	*Cuscuta reflexa* Roxb.	Convolvulaceae	P
154	*Cyanthillium cinereum* (L.) H.Rob.	Asteraceae	H
155	*Cyathocline purpurea* (Buch.-Ham. ex D.Don) Kuntze	Asteraceae	H
156	*Cyathula prostrata* (L.) Blume	Amaranthaceae	H
157	*Cyclea peltata* (Lam.) Hook.f. & Thomson	Menispermaceae	C
158	*Cynarospermum asperrimum* (Nees) Vollesen	Acanthaceae	H
159	*Cynodon dactylon* (L.) Pers.	Poaceae	G
160	*Cynodon radiatus* Roth	Poaceae	G
161	*Cynoglossum zeylanicum* (Vahl) Brand	Boraginaceae	H
162	*Cynometra iripa* Kostel.	Leguminosae	T
163	*Cyperus difformis* L.	Cyperaceae	H
164	*Dalbergia horrida* (Dennst.) Mabb.	Leguminosae	C
165	*Dalbergia latifolia* Roxb.	Leguminosae	T
166	*Dalbergia rubiginosa* Roxb.	Leguminosae	C

	Botanical name	Family	Habit
167	*Dalbergia volubilis* Roxb.	Leguminosae	C
168	*Datura stramonium* L.	Solanaceae	H
169	*Debregeasia longifolia* (Burm.f.) Wedd.	Urticaceae	S
170	*Dendrobium barbatulum* Lindl.	Orchidaceae	E
171	*Dendrobium herbaceum* Lindl.	Orchidaceae	E
172	*Dendrobium heyneanum* Lindl.	Orchidaceae	E
173	*Dendrobium macrostachyum* Lindl.	Orchidaceae	E
174	*Dendrobium ovatum* (L.) Kraenzl.	Orchidaceae	E
175	*Dendrocalamus strictus* (Roxb.) Nees	Poaceae	G
176	*Dendrolobium triangulare* (Retz.) Schindl.	Leguminosae	S
177	*Dendrophthoe coccinea* (Jack) G.Don	Loranthaceae	P
178	*Dendrophthoe falcata* (L.f.) Ettingsh.	Loranthaceae	P
179	*Derris benthamii* (Thwaites) Thwaites	Leguminosae	C
180	*Desmodium triflorum* (L.) DC.	Leguminosae	H
181	*Desmos chinensis* Lour.	Annonaceae	C
182	*Dichapetalum gelonioides* (Roxb.) Engl.	Dichapetalaceae	S
183	*Dichrocephala integrifolia* (L.f.) Kuntze	Asteraceae	H
184	*Dicliptera chinensis* (L.) Juss.	Acanthaceae	H
185	*Dillenia pentagyna* Roxb.	Dilleniaceae	T
186	*Dimocarpus longan* Lour.	Sapindaceae	T
187	*Dioscorea bulbifera* L.	Dioscoreaceae	C
188	*Dioscorea oppositifolia* L.	Dioscoreaceae	C
189	*Dioscorea pentaphylla* L.	Dioscoreaceae	C
190	*Diospyros buxifolia* (Blume) Hiern	Ebenaceae	T
191	*Diospyros candolleana* Wight	Ebenaceae	T
192	*Diospyros ebenum* J.Koenig ex Retz.	Ebenaceae	T
193	*Diospyros melanoxylon* Roxb.	Ebenaceae	T
194	*Diospyros montana* Roxb.	Ebenaceae	T
195	*Diospyros oocarpa* Thwaites	Ebenaceae	T
196	*Diospyros paniculata* Dalzell	Ebenaceae	T
197	*Diospyros saldanhae* Kosterm.	Ebenaceae	T
198	*Diploclisia glaucescens* (Blume) Diels	Menispermaceae	C
199	*Dipteracanthus prostratus* (Poir.) Nees	Acanthaceae	H
200	*Dipterocarpus indicus* Bedd.	Dipterocarpaceae	T
201	*Dombeya wallichii* (Lindl.) K.Schum. *	Malvaceae	T
202	*Drosera burmanni* Vahl	Droseraceae	H
203	*Drosera indica* L.	Droseraceae	H
204	*Duabanga grandiflora* (DC.) Walp. *	Lythraceae	T
205	*Duranta erecta* L.	Verbenaceae	S
206	*Dysoxylum malabaricum* Bedd. ex C.DC.	Meliaceae	T
207	*Ecbolium ligustrinum* (Vahl) Vollesen	Acanthaceae	H
208	*Eclipta prostrata* (L.) L.	Asteraceae	H
209	*Elaeagnus conferta* Roxb.	Elaeagnaceae	C
210	*Elaeocarpus serratus* L.	Elaeocarpaceae	T
211	*Elaeocarpus tuberculatus* Roxb.	Elaeocarpaceae	T
212	*Elatostema lineolatum* Wight	Urticaceae	H
213	*Elephantopus scaber* L.	Asteraceae	H
214	*Elytranthe parasitica* (L.) Danser	Loranthaceae	P
215	*Embelia ribes* Burm.f.	Primulaceae	C
216	*Embelia tsjeriam-cottam* (Roem. & Schult.) A.DC.	Primulaceae	C
217	*Epipogium roseum* (D.Don) Lindl	Orchidaceae	H
218	*Eranthemum capense* L.	Acanthaceae	S
219	*Eriocaulon cinereum* R.Br.	Eriocaulaceae	H
220	*Eriocaulon heterolepis* Steud.	Eriocaulaceae	H
221	*Erycibe paniculata* Roxb.	Convolvulaceae	C
222	*Eryngium foetidum* L.	Apiaceae	H
223	*Erythrina suberosa* Roxb.	Leguminosae	T
224	*Erythrina variegata* L. *	Leguminosae	T
225	*Erythropalum scandens* Blume	Olacaceae	C
226	*Eugenia phillyraeoides* Trimen	Myrtaceae	S
227	*Eugenia roxburghii* DC.	Myrtaceae	T
228	*Euonymus indicus* B.Heyne ex Wall.	Celastraceae	T
229	*Euphorbia hirta* L.	Euphorbiaceae	H
230	*Euphorbia pulcherrima* Willd. ex Klotzsch	Euphorbiaceae	S
231	*Euphorbia thymifolia* L.	Euphorbiaceae	H
232	*Eurya nitida* Korth.	Pentaphylacaceae	T
233	*Fagraea ceilanica* Thunb.	Gentianaceae	E
234	*Falconeria insignis* Royle	Euphorbiaceae	T
235	*Ficus bengalensis* L.	Moraceae	T
236	*Ficus benjamina* L.	Moraceae	T
237	*Ficus drupacea* Thunb.	Moraceae	T
238	*Ficus microcarpa* L.f.	Moraceae	T
239	*Ficus nervosa* B.Heyne ex Roth	Moraceae	T
240	*Ficus racemosa* L.	Moraceae	T
241	*Ficus religiosa* L.	Moraceae	T
242	*Ficus tsjahela* Burm. f.	Moraceae	T
243	*Ficus virens* Aiton	Moraceae	T
244	*Flacourtia montana* J.Graham	Salicaceae	T
245	*Flemingia strobilifera* (L.) W.T.Aiton	Leguminosae	S
246	*Galinsoga parviflora* Cav.	Asteraceae	H
247	*Garcinia gummi-gutta* (L.) Roxb.	Clusiaceae	T
248	*Garcinia indica* (Thouars) Choisy *	Clusiaceae	T
249	*Garcinia morella* (Gaertn.) Desr.	Clusiaceae	T
250	*Garcinia talbotii* Raizada ex Santapau	Clusiaceae	T

	Botanical name	Family	Habit
251	*Garcinia xanthochymus* Hook.f. ex T.Anderson	Clusiaceae	T
252	*Geissaspis cristata* Wight & Arn.	Leguminosae	H
253	*Genianthus laurifolius* (Roxb.) Hook.f.	Apocynaceae	C
254	*Girardinia diversifolia* (Link) Friis	Urticaceae	H
255	*Gliricidia sepium* (Jacq.) Walp. *	Leguminosae	T
256	*Glochidion ellipticum* Wight	Phyllanthaceae	T
257	*Glochidion zeylanicum* (Gaertn.) A.Juss.	Phyllanthaceae	T
258	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	S
259	*Gmelina arborea* Roxb.	Lamiaceae	T
260	*Gnidia glauca* (Fresen.) Gilg	Thymelaeaceae	S
261	*Gonostegia pentandra* (Roxb.) Miq.	Urticaceae	S
262	*Gordonia obtusa* Wall. ex Wight	Theaceae	T
263	*Gouania microcarpa* DC.	Rhamnaceae	C
264	*Grewia heterotricha* Mast.	Malvaceae	C
265	*Grewia tiliifolia* Vahl	Malvaceae	T
266	*Grewia umbellifera* Bedd.	Malvaceae	C
267	*Gymnema sylvestre* (Retz.) R.Br. ex Sm.	Apocynaceae	C
268	*Gymnostachyum latifolium* T.Anderson	Acanthaceae	H
269	*Gymnostachyum polyanthum* Wight	Acanthaceae	H
270	*Haldina cordifolia* (Roxb.) Ridsdale	Rubiaceae	T
271	*Harpullia arborea* (Blanco) Radlk.	Sapindaceae	T
272	*Helicanthes elastica* (Desr.) Danser	Loranthaceae	P
273	*Helicia nilagirica* Bedd.	Proteaceae	T
274	*Helicteres isora* L.	Malvaceae	S
275	*Helixanthera wallichiana* Danser	Loranthaceae	P
276	*Hemidesmus indicus* (L.) R. Br. ex Schult.	Apocynaceae	C
277	*Hemigraphis latebrosa* (Roth) Nees	Acanthaceae	H
278	*Heynea trijuga* Roxb. ex Sims	Meliaceae	T
279	*Hibiscus hispidissimus* Griff.	Malvaceae	C
280	*Hibiscus rosa-sinensis* L. *	Malvaceae	S
281	*Hibiscus rostellatus* Guill. & Perr.	Malvaceae	C
282	*Hippeastrum puniceum* (Lam.) Voss	Amaryllidaceae	H
283	*Holarrhena pubescens* Wall. ex G.Don	Apocynaceae	T
284	*Holigarna arnottiana* Hook.f.	Anacardiaceae	T
285	*Holigarna grahamii* (Wight) Kurz	Anacardiaceae	T
286	*Homalium ceylanicum* (Gardner) Benth.	Salicaceae	T
287	*Homonoia riparia* Lour.	Euphorbiaceae	S
288	*Hopea canarensis* Hole	Dipterocarpaceae	T
289	*Hopea parviflora* Bedd.	Dipterocarpaceae	T
290	*Hopea ponga* (Dennst.) Mabb.	Dipterocarpaceae	T
291	*Hoya wightii* Hook.f.	Apocynaceae	E

	Botanical name	Family	Habit
292	*Hubbardia heptaneuron* Bor	Poaceae	G
293	*Hugonia mystax* L.	Linaceae	C
294	*Humboldtia brunonis* Wall.	Leguminosae	T
295	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Achariaceae	T
296	*Hydrocotyle javanica* Thunb.	Araliaceae	H
297	*Hygrophila auriculata* (Schumach.) Heine	Acanthaceae	H
298	*Hymenodictyon obovatum* Wall.	Rubiaceae	T
299	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	S
300	*Ichnocarpus frutescens* (L.) W.T.Aiton	Apocynaceae	C
301	*Impatiens acaulis* Arn.	Balsaminaceae	H
302	*Impatiens balsamina* L.	Balsaminaceae	H
303	*Impatiens barberi* Hook.f.	Balsaminaceae	H
304	*Impatiens minor* (DC.) S.M. Almeida	Balsaminaceae	H
305	*Impatiens oppositifolia* L.	Balsaminaceae	H
306	*Impatiens scapiflora* B.Heyne ex Roxb.	Balsaminaceae	H
307	*Ipomoea hederifolia* L.	Convolvulaceae	C
308	*Ipomoea obscura* (L.) Ker Gawl.	Convolvulaceae	C
309	*Ipomoea staphylina* Roem. & Schult.	Convolvulaceae	C
310	*Isodon lophanthoides* (Buch.-Ham. ex D.Don) H.Hara	Lamiaceae	H
311	*Ixora brachiata* Roxb.	Rubiaceae	T
312	*Ixora coccinea* L.	Rubiaceae	S
313	*Ixora nigricans* R.Br. ex Wight & Arn.	Rubiaceae	S
314	*Jasminum coarctatum* Roxb.	Oleaceae	C
315	*Jasminum flexile* Vahl	Oleaceae	C
316	*Jasminum malabaricum* Wight	Oleaceae	C
317	*Jasminum multiflorum* (Burm.f.) Andrews *	Oleaceae	S
318	*Justicia japonica* Thunb.	Acanthaceae	H
319	*Justicia procumbens* Blume	Acanthaceae	H
320	*Justicia wynaadensis* B.Heyne	Acanthaceae	H
321	*Kamettia caryophyllata* (Roxb.) Nicolson & Suresh	Apocynaceae	C
322	*Knema attenuata* Warb.	Myristicaceae	T
323	*Kunstleria keralensis* C.N.Mohanan & N.C.Nair	Leguminosae	C
324	*Kydia calycina* Roxb.	Malvaceae	T
325	*Lagenandra toxicaria* Dalzell	Araceae	H
326	*Lagerstroemia lanceolata* Wall.	Lythraceae	T
327	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	T
328	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	T
329	*Lantana camara* L.	Verbenaceae	S
330	*Laportea interrupta (L.) Chew*	Urticaceae	H
331	*Leea asiatica* (L.) Ridsdale	Vitaceae	T
332	*Leea indica* (Burm. f.) Merr.	Vitaceae	T
333	*Lepidagathis cuspidata* Nees	Acanthaceae	H

	Botanical name	Family	Habit
334	*Lepidagathis incurva* Buch.-Ham. ex D. Don	Acanthaceae	H
335	*Leucas aspera* (Willd.) Link	Lamiaceae	H
336	*Leucas biflora* (Vahl) Sm.	Lamiaceae	H
337	*Leucas marrubioides* Desf.	Lamiaceae	H
338	*Leucas stelligera* Wall. ex Benth.	Lamiaceae	H
339	*Ligustrum perrottetii* A.DC.	Oleaceae	S
340	*Limnophila indica* (L.) Druce	Plantaginaceae	H
341	*Limnophila repens* (Benth.) Benth.	Plantaginaceae	H
342	*Lindernia ciliata* (Colsm.) Pennell	Linderniaceae	H
343	*Lindernia crustacea* (L.) F.Muell.	Linderniaceae	H
344	*Lindernia pusilla* (Willd.) Bold.	Linderniaceae	H
345	*Litsea floribunda* Gamble	Lauraceae	T
346	*Litsea ghatica* Saldanha	Lauraceae	S
347	*Litsea laevigata* Gamble	Lauraceae	T
348	*Lobelia alsinoides* Lam.	Companulaceae	H
349	*Loeseneriella ovata* (Lam.) M.R.Almeida	Celastraceae	C
350	*Lophopetalum wightianum* Arn.	Celastraceae	T
351	*Loranthus globosus* Roxb.	Loranthaceae	P
352	*Ludwigia hyssopifolia* (G.Don) Exell	Onagraceae	H
353	*Luvunga sarmentosa* Kurz	Rutaceae	C
354	*Lycianthes laevis* (Dunal) Bitter	Solanaceae	S
355	*Macaranga peltata* (Roxb.) Müll. Arg.	Euphorbiaceae	T
356	*Mackenziea integrifolia* (Dalzell) Bremek.	Acanthaceae	S
357	*Madhuca neriifolia* (Moon) H.J.Lam	Sapotaceae	T
358	*Maesa indica* (Roxb.) A. DC.	Primulaceae	S
359	*Magnolia champaca* (L.) Baill. ex Pierre	Magnoliaceae	T
360	*Mallotus nudiflorus* (L.) Kulju & Welzen	Euphorbiaceae	T
361	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae	T
362	*Mallotus tetracoccus* (Roxb.) Kurz	Euphorbiaceae	T
363	*Mangifera indica* L.	Anacardiaceae	T
364	*Margaritaria indica* (Dalzell) Airy Shaw	Phyllanthaceae	T
365	*Marsdenia raziana* Yogan. & Subr.	Apocynaceae	C
366	*Mastixia arborea* (Wight) C.B.Clarke	Cornaceae	T
367	*Maytenus rothiana* (Walp.) Lobreau-Callen	Celastraceae	S
368	*Mecardonia procumbens* (Mill.) Small	Plantaginaceae	H
369	*Memecylon malabaricum* (C.B.Clarke) Cogn.	Melastomataceae	S
370	*Memecylon talbotianum* Brandis	Melastomataceae	T
371	*Memecylon terminale* Dalzell	Melastomataceae	S
372	*Memecylon umbellatum* Burm. f.	Melastomataceae	T
373	*Merremia umbellata* (L.) Hallier f.	Convolvulaceae	C
374	*Mesua ferrea* L.	Calophyllaceae	T
375	*Mikania micrantha* Kunth	Asteraceae	C
376	*Mimosa pudica* L.	Leguminosae	H
377	*Mimusops elengi* L.	Sapotaceae	T
378	*Mirabilis jalapa* L. *	Nyctaginaceae	H
379	*Mitragyna parvifolia* (Roxb.) Korth.	Rubiaceae	T
380	*Moullava spicata* (Dalzell) Nicolson	Leguminosae	C
381	*Mucuna monosperma* Wight	Leguminosae	C
382	*Mukia maderaspatana* (L.) M.Roem.	Cucurbitaceae	C
383	*Munronia pinnata* (Wall.) W.Theob.	Meliaceae	H
384	*Murdannia simplex* (Vahl) Brenan	Commelinaceae	H
385	*Mussaenda glabrata* (Hook.f.) Hutch. ex Gamble	Rubiaceae	C
386	*Mussaenda laxa* (Hook.f.) Hutch. ex Gamble	Rubiaceae	C
387	*Myristica dactyloides* Gaertn.	Myristicaceae	T
388	*Myristica malabarica* Lam	Myristicaceae	T
389	*Naravelia zeylanica* (L.) DC.	Menispermaceae	C
390	*Naregamia alata* Wight & Arn.	Meliaceae	H
391	*Neolamarckia cadamba* (Roxb.) Bosser *	Rubiaceae	T
392	*Nilgirianthus ciliatus* (Nees) Bremek.	Acanthaceae	S
393	*Nilgirianthus heyneanus* (Nees) Bremek.	Acanthaceae	H
394	*Nilgirianthus lupulinus* (Nees) Bremek.	Acanthaceae	S
395	*Nothapodytes nimmoniana* (J.Graham) Mabb.	Icacinaceae	T
396	*Nothopegia beddomei* Gamble	Anacardiaceae	T
397	*Nothopegia racemosa* (Dalzell) Ramamoorthy	Anacardiaceae	T
398	*Oberonia brunoniana* Wight	Orchidaceae	E
399	*Oberonia falconeri* Hook.f.	Orchidaceae	E
400	*Ochlandra scriptoria* (Dennst.) C.E.C.Fisch.	Poaceae	G
401	*Ocimum basilicum* L.	Lamiaceae	H
402	*Oldenlandia auricularia* (L.) K.Schum.	Rubiaceae	H
403	*Oldenlandia corymbosa* L.	Rubiaceae	H
404	*Oldenlandia diffusa* (Willd.) Roxb.	Rubiaceae	H
405	*Oldenlandia herbacea* (L.) Roxb.	Rubiaceae	H
406	*Olea dioica* Roxb.	Oleaceae	T
407	*Ophiorrhiza mungos* L.	Rubiaceae	H
408	*Oplismenus compositus* (L.) P.Beauv.	Poaceae	G
409	*Osbeckia cupularis* D. Don ex Wight & Arn.	Melastomataceae	S
410	*Osbeckia parvifolia* Arn.	Melastomataceae	H
411	*Osyris lanceolata* Hochst. & Steud.	Santalaceae	S
412	*Oxalis corniculata* L.	Oxalidaceae	H

	Botanical name	Family	Habit
413	*Oxyceros rugulosus* (Thwaites) Tirveng.	Rubiaceae	C
414	*Pajanelia longifolia* (Willd.) K.Schum.	Bignoniaceae	T
415	*Pandanus furcatus* Roxb.	Pandanaceae	S
416	*Paracroton pendulus* subsp. *zeylanicus* (Thwaites) N.P.Balakr. & Chakrab.	Euphorbiaceae	T
417	*Paramignya monophylla* Wight	Rutaceae	C
418	*Parsonsia alboflavescens* (Dennst.) Mabb.	Apocynaceae	C
419	*Pavetta crassicaulis* Bremek.	Rubiaceae	S
420	*Pavetta hispidula* Wight & Arn.	Rubiaceae	S
421	*Pavetta indica* L.	Rubiaceae	S
422	*Pavonia odorata* Willd.	Malvaceae	H
423	*Persea macrantha* (Nees) Kosterm.	Lauraceae	T
424	*Persicaria chinensis* (L.) H. Gross	Polygonaceae	H
425	*Persicaria glabra* (Willd.) M.Gómez	Polygonaceae	H
426	*Phaulopsis imbricata* (Forssk.) Sweet	Acanthaceae	H
427	*Philodendron hederaceum* (Jacq.) Schott	Araceae	C
428	*Phyllanthus amarus* Schumach. & Thonn.	Phyllanthaceae	H
429	*Phyllanthus emblica* L.	Phyllanthaceae	T
430	*Phyllanthus reticulatus* Poir.	Phyllanthaceae	S
431	*Phyllanthus urinaria* L.	Phyllanthaceae	H
432	*Phyllocephalum scabridum* (DC.) K.Kirkman	Asteraceae	H
433	*Physalis minima* L.	Solanaceae	H
434	*Pilea microphylla* (L.) Liebm.	Urticaceae	H
435	*Pimpinella heyneana* (DC.) Benth.	Apiaceae	H
436	*Pinanga dicksonii* (Roxb.) Blume	Arecaceae	S
437	*Piper hookeri* Miq.	Piperaceae	C
438	*Piper hymenophyllum* (Miq.) Wight	Piperaceae	C
439	*Piper umbellatum* L.	Piperaceae	H
440	*Pittosporum dasycaulon* Miq.	Pittosporaceae	T
441	*Plectranthus mollis* (Aiton) Spreng.	Lamiaceae	H
442	*Plumbago zeylanica* L.	Plumbaginaceae	H
443	*Poeciloneuron indicum* Bedd.	Calophyllaceae	T
444	*Pogostemon benghalensis* (Burm.f.) Kuntze	Lamiaceae	H
445	*Pogostemon deccanensis* (Panigrahi) Press	Lamiaceae	H
446	*Pogostemon paniculatus* (Willd.) Benth.	Lamiaceae	H
447	*Polyalthia fragrans* (Dalzell) Benth. & Hook. f.	Annonaceae	T
448	*Polytrias indica* (Houtt.) Veldkamp	Poaceae	G
449	*Premna coriacea* C.B.Clarke	Lamiaceae	C
450	*Prunus ceylanica* (Wight) Miq.	Rosaceae	T
451	*Pseuderanthemum malabaricum* Gamble	Acanthaceae	S
452	*Psychotria dalzellii* Hook.f.	Rubiaceae	S
453	*Psychotria flavida* Talbot	Rubiaceae	S
454	*Psychotria nigra* (Gaertn.) Alston	Rubiaceae	S
455	*Psydrax dicoccos* Gaertn.	Rubiaceae	T
456	*Pterocarpus marsupium* Roxb.	Leguminosae	T
457	*Pterospermum diversifolium* Blume	Sterculiaceae	T
458	*Rapanea wightiana* (Wall. ex A. DC.) Mez	Primulaceae	S
459	*Rhynchospora wightiana* (Nees) Steud.	Cyperaceae	H
460	*Rhynchostylis retusa* (L.) Blume	Orchidaceae	E
461	*Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne	Lythraceae	H
462	*Rubus fockei* Gandhi	Rosaceae	C
463	*Rungia pectinata* (L.) Nees	Acanthaceae	H
464	*Sacciolepis indica* (L.) Chase	Poaceae	G
465	*Salacia malabarica* Gamble	Celastraceae	C
466	*Salacia oblonga* Wall.	Celastraceae	C
467	*Santalum album* L.	Santalaceae	T
468	*Sapindus trifoliatus* L.	Sapindaceae	T
469	*Saprosma glomeratum* (Gardner) Bedd.	Rubiaceae	S
470	*Saraca asoca* (Roxb.) Willd.	Leguminosae	T
471	*Sarcostigma kleinii* Wight & Arn.	Icacinaceae	C
472	*Schefflera actinophylla* (Endl.) Harms	Araliaceae	C
473	*Schefflera venulosa* (Wight & Arn.) Harms	Araliaceae	C
474	*Schefflera wallichiana* (Wight & Arn.) Harms	Araliaceae	C
475	*Schleichera oleosa* (Lour.) Merr.	Sapindaceae	T
476	*Senecio bombayensis* N.P.Balakr.	Asteraceae	H
477	*Senna alata* (L.) Roxb. *	Leguminosae	T
478	*Senna hirsuta* (L.) H.S.Irwin & Barneby	Leguminosae	H
479	*Senna occidentalis* (L.) Link	Leguminosae	H
480	*Senna sophera* (L.) Roxb.	Leguminosae	H
481	*Senna tora* (L.) Roxb.	Leguminosae	H
482	*Sida rhombifolia* L.	Malvaceae	H
483	*Smilax zeylanica* L.	Smilacaceae	C
484	*Smythea bombaiensis* (Dalzell) S.P.Banerjee & P.K.Mukh	Rhamnaceae	C
485	*Solanum americanum* Mill.	Solanaceae	H
486	*Solanum lasiocarpum* Dunal	Solanaceae	S
487	*Solanum torvum* Sw.	Solanaceae	H
488	*Solanum viarum* Dunal	Solanaceae	H
489	*Solanum violaceum* Ortega	Solanaceae	H
490	*Solanum virginianum* L.	Solanaceae	H
491	*Sonchus oleraceus* (L.) L.	Asteraceae	H
492	*Sonerila rheedei* Wall.	Melastomataceae	H
493	*Spathodea campanulata* P.Beauv. *	Bignoniaceae	T

	Botanical name	Family	Habit
494	*Spermacoce articularis* L.f.	Rubiaceae	H
495	*Spermacoce exilis* (L.O.Williams) C.D.Adams ex W.C.Burger & C.M.Taylor	Rubiaceae	H
496	*Spermacoce hispida* L.	Rubiaceae	H
497	*Spermacoce ocymoides* Burm.f.	Rubiaceae	H
498	*Sphaeranthus indicus* L.	Asteraceae	H
499	*Sphagneticola trilobata* (L.) Pruski	Asteraceae	H
500	*Stachytarpheta indica* (L.) Vahl	Verbenaceae	H
501	*Staurogyne zeylanica* Kuntze	Acanthaceae	H
502	*Stephania japonica* (Thunb.) Miers	Menispermaceae	C
503	*Sterculia guttata* Roxb. ex G.Don	Malvaceae	T
504	*Stereospermum tetragonum* DC.	Bignoniaceae	T
505	*Streblus asper* Lour.	Moraceae	T
506	*Strychnos colubrina* L.	Loganiaceae	C
507	*Strychnos nux-vomica* L.	Loganiaceae	T
508	*Symplocos cochinchinensis* (Lour.) S. Moore	Symplocaceae	T
509	*Symplocos racemosa* Roxb.	Symplocaceae	T
510	*Syzygium caryophyllatum* (L.) Alston	Myrtaceae	T
511	*Syzygium cumini* (L.) Skeels	Myrtaceae	T
512	*Syzygium gardneri* Thwaites	Myrtaceae	T
513	*Syzygium hemisphericum* (Wight) Alston	Myrtaceae	T
514	*Syzygium jambos* (L.) Alston *	Myrtaceae	T
515	*Syzygium laetum* (Buch.-Ham.) Gandhi	Myrtaceae	T
516	*Syzygium zeylanicum* (L.) DC.	Myrtaceae	T
517	*Tabernaemontana alternifolia* L.	Apocynaceae	T
518	*Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult.	Apocynaceae	S
519	*Tadehagi triquetrum* (L.) H.Ohashi	Leguminosae	H
520	*Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre	Rubiaceae	T
521	*Taxillus ferrugineus* (Jack) Bân	Loranthaceae	P
522	*Tectona grandis* L.f. *	Verbenaceae	T
523	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	T
524	*Terminalia catappa* L. *	Combretaceae	T
525	*Terminalia chebula* Retz.	Combretaceae	T
526	*Terminalia paniculata* Roth	Combretaceae	T
527	*Terminalia tomentosa* Wight & Arn.	Combretaceae	T
528	*Tetrastigma gamblei* B.V.Shetty & P.Singh	Vitaceae	C
529	*Tetrastigma sulcatum* (P. Lawson) Gamble	Vitaceae	C
530	*Thelepaepale ixiocephala* (Benth.) Bremek.	Acanthaceae	S
531	*Themeda tremula* (Nees ex Steud.) Hack.	Poaceae	G
532	*Themeda triandra* Forssk.	Poaceae	G
533	*Thespesia lampas* (Cav.) Dalzell	Malvaceae	H
534	*Thottea siliquosa* (Lam.) Ding Hou	Aristolochiaceae	S
535	*Thunbergia alata* Bojer ex Sims	Acanthaceae	H
536	*Thunbergia fragrans* Roxb.	Acanthaceae	H
537	*Thunbergia grandiflora* (Roxb. ex Rottl.) Roxb. *	Acanthaceae	C
538	*Thunbergia mysorensis* (Wight) T.Anderson	Acanthaceae	C
539	*Tinospora malabarica* (Lam.) Hook. f. & Thomson	Menispermaceae	C
540	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	C
541	*Tolypanthus lageniferus* Tiegh.	Loranthaceae	P
542	*Tragia hispida* Willd.	Euphorbiaceae	C
543	*Trema orientalis* (L.) Blume	Cannabaceae	T
544	*Trias stocksii* Benth. ex Hook.f.	Orchidaceae	E
545	*Trichosanthes tricuspidata* Lour.	Cucurbitaceae	C
546	*Tridax procumbens* (L.) L.	Asteraceae	H
547	*Triumfetta rhomboidea* Jacq.	Malvaceae	H
548	*Turpinia cochinchinensis* (Lour.) Merr.	Staphyleaceae	T
549	*Turraea pubescens* Hell.	Meliaceae	C
550	*Tylophora asthmatica* (L. f.) Wight & Arn.	Apocynaceae	C
551	*Urena lobata* L.	Malvaceae	H
552	*Utricularia caerulea* L.	Lentibulariaceae	H
553	*Utricularia reticulata* Sm.	Lentibulariaceae	H
554	*Utricularia striatula* Sm.	Lentibulariaceae	H
555	*Vallaris solanacea* (Roth) Kuntze	Apocynaceae	C
556	*Vateria indica* L.	Dipterocarpaceae	T
557	*Ventilago denticulata* Willd.	Rhamnaceae	C
558	*Ventilago maderaspatana* Gaertn.	Rhamnaceae	C
559	*Vepris bilocularis* Engl.	Rutaceae	T
560	*Vincetoxicum pauciflorum* (Wight & Arn.) Kuntze	Apocynaceae	C
561	*Viscum angulatum* B.Heyne ex DC.	Santalaceae	P
562	*Vitex leucoxylon* L.f.	Lamiaceae	T
563	*Wendlandia thyrsoidea* (Roth) Steud.	Rubiaceae	T
564	*Withania somnifera* (L.) Dunal *	Solanaceae	H
565	*Wrightia tinctoria* R.Br.	Apocynaceae	T
566	*Xylia xylocarpa* (Roxb.) Taub.	Leguminosae	T
567	*Xyris pauciflora* Willd.	Xyridaceae	H
568	*Zingiber cernuum* Dalzell	Zingiberaceae	H
569	*Ziziphus oenopolia* (L.) Mill.	Rhamnaceae	C
570	*Ziziphus rugosa* Lam.	Rhamnaceae	T

T—Trees | H—Herb | S—Shrub | E—Epiphyte | C—Climber | P—Parasite | G—Grass | *—introduced to the Agumbe region

Annexure 2. Threatened plants of Agumbe region of central Western Ghats, Karnataka (IUCN 2017).

	Botanical Name	Family	Habit	RET status
1	*Actinodaphne wightiana* (Kuntze) Noltie	Lauraceae	T	NT
2	*Adenia hondala* (Gaertn.) W.J.de Wilde	Passifloraceae	C	EN
3	*Aglaia lawii* (Wight) C.J.Saldanha	Meliaceae	T	R
4	*Ampelocissus indica* (L.) Planch.	Vitaceae	C	VU
5	*Arenga wightii* Griff.	Arecaceae	T	VU
6	*Aristolochia tagala* Cham.	Aristolochiaceae	C	NT
7	*Artocarpus hirsutus* Lam.	Moraceae	T	VU
8	*Beilschmiedia dalzellii* (Meisn.) Kosterm.	Lauraceae	T	NT
9	*Casearia rubescens* Dalzell	Salicaceae	T	NE
10	*Celastrus paniculatus* Willd.	Celastraceae	C	NT
11	*Chonemorpha fragrans* (Moon) Alston	Apocynaceae	C	NE
12	*Cinnamomum malabatrum* (Burm.f.) J.Presl	Lauraceae	T	NE
13	*Dalbergia horrida* (Dennst.) Mabb.	Leguminosae	C	NE
14	*Dalbergia latifolia* Roxb.	Leguminosae	T	VU
15	*Derris benthamii* (Thwaites) Thwaites	Leguminosae	C	NT
16	*Diospyros candolleana* Wight	Ebenaceae	T	VU
17	*Diospyros paniculata* Dalzell	Ebenaceae	T	NT
18	*Diospyros saldanhae* Kosterm.	Ebenaceae	T	NE
19	*Dipterocarpus indicus* Bedd.	Dipterocarpaceae	T	EN
20	*Drosera indica* L.	Droseraceae	H	LC
21	*Embelia tsjeriam-cottam* (Roem. & Schult.) A.DC.	Primulaceae	C	VU
22	*Epipogium roseum* (D.Don) Lindl	Orchidaceae	H	NE
23	*Garcinia gummi-gutta* (L.) Roxb.	Clusiaceae	T	NT
24	*Garcinia indica* (Thouars) Choisy	Clusiaceae	T	NE
25	*Garcinia morella* (Gaertn.) Desr.	Clusiaceae	T	NE
26	*Glochidion zeylanicum* (Gaertn.) A.Juss.	Phyllanthaceae	T	NE
27	*Grewia heterotricha* Mast.	Malvaceae	C	NE
28	*Holigarna grahamii* (Wight) Kurz	Anacardiaceae	T	NE
29	*Hopea canarensis* Hole	Dipterocarpaceae	T	EN
30	*Hopea parviflora* Bedd.	Dipterocarpaceae	T	EN
31	*Hopea ponga* (Dennst.) Mabb.	Dipterocarpaceae	T	EN
32	*Hydnocarpus pentandrus* (Buch.-Ham.) Oken	Achariaceae	T	LC
33	*Impatiens acaulis* Arn.	Balsaminaceae	H	LC
34	*Knema attenuata* Warb.	Myristicaceae	T	LC
35	*Kunstleria keralensis* C.N.Mohanan & N.C.Nair	Leguminosae	C	EN
36	*Madhuca neriifolia* (Moon) H.J.Lam	Sapotaceae	T	EN
37	*Marsdenia raziana* Yogan. & Subr.	Apocynaceae	C	R
38	*Memecylon malabaricum* (C.B.Clarke) Cogn.	Melastomataceae	S	R
39	*Mesua ferrea* L.	Calophyllaceae	T	NT
40	*Mimusops elengi* L.	Sapotaceae	T	NT
41	*Myristica dactyloides* Gaertn.	Myristicaceae	T	NT
42	*Myristica malabarica* Lam.	Myristicaceae	T	VU
43	*Nilgirianthus ciliatus* (Nees) Bremek	Acanthaceae	S	NE
44	*Nothopegia beddomei* Gamble	Anacardiaceae	T	NT
45	*Persea macrantha* (Nees) Kosterm.	Lauraceae	T	VU
46	*Pittosporum dasycaulon* Miq.	Pittosporaceae	T	NT
47	*Salacia malabarica* Gamble	Celastraceae	C	EN
48	*Salacia oblonga* Wall.	Celastraceae	C	VU
49	*Santalum album* L.	Santalaceae	T	VU
50	*Saraca asoca* (Roxb.) Willd.	Leguminosae	T	VU
51	*Smilax zeylanica* L.	Smilacaceae	C	LC
52	*Symplocos cochinchinensis* (Lour.) S. Moore	Symplocaceae	T	NT
53	*Tabernaemontana alternifolia* L.	Apocynaceae	T	NE
54	*Thottea siliquosa* (Lam.) Ding Hou	Aristolochiaceae	S	NT
55	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	C	NE
56	*Vateria indica* L.	Dipterocarpaceae	T	CR
57	*Vepris bilocularis* Engl.	Rutaceae	T	NT
58	*Vitex leucoxylon* L.f.	Lamiaceae	T	R

CR—Critically Endangered | EN—Endangered | VU—Vulnareble; |NT—Near Threatened | R—Rare | LC—Least concern | NE—Not Evaluated.

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COMMUNICATION

Population assessment and habitat distribution modelling of the threatened medicinal plant *Picrorhiza kurroa* Royle ex Benth. in the Kumaun Himalaya, India

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Abstract: Kumaun Himalaya is a home to various threatened medicinal and aromatic plants. *Picrorhiza kurroa* is a threatened medicinal plant useful in curing many diseases in Indian Himalayan region. Due to overharvesting from the wild its population is decreasing at an alarming rate. The present study attempted to assess its availability and predict highly suitable areas for in situ conservation in the alpine region of Kumaun. Availability of *P. kurroa* across various meadows was evaluated through rapid mapping exercise. MaxEnt model was used to predict the geographical distribution of the species using various environmental and physiographic parameters, and 29 primary distribution points. The results reveal that potential habitat of *P. kurroa* is located near forest fringes. Of the 3,828km^2 area (vegetated) of the alpine region of Kumaun, about 202km^2 is recorded highly suitable, 489km^2 less suitable and the rest not suitable for the species. It is also revealed that Napalchu nala, Panchachuli base, Chhipla Kedar, Rongkong, Ralam, Milam, Dwali, and Pindari areas are highly suitable areas for distribution of *P. kurroa*.

Keywords: Distribution, Kumaun Himalaya, medicinal plant, population.

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Author contributions: NC contributed for site selection, field survey, data collection, analysis and finalization of the manuscript. GS has help in the field work, data evaluation, continuous review and finalization of manuscript. SL has participated in field work and compilation of data. MPS has constantly guided the work and provide all the necessary technical support and preparation of manuscript. LM assisted in the field work and analysis of data.

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INTRODUCTION

Picrorhiza kurroa (Scrophulariaceae; vernacular name Kutki) (Image 1) is a perennial herb confined to alpine region of the Himalaya. The species is native to India, Nepal, Bhutan, China, Tibet, and Pakistan. In India, *P. kurroa* is naturally distributed from Kashmir to Sikkim in the subalpine to alpine region between 3,000–5,300 m (Chettri et al. 2005). It prefers rocky crevices and grows on moist, rocky slopes in organic rich soil. It is used either as an adulterant or as a substitute for the Indian Gentian *Gentiana kurroo*. Odour of the stem is slight and unpleasant, taste is very bitter and long lasting, and it has a high demand in the herbal market (Dutt 1928; Ved & Goraya 2008). A drug named picroliv (iridoid glycoside fraction of roots and rhizomes) containing at least 60% of 1:1.5 mixture of picroside-I and kutkoside) has been developed for the treatment of acute and chronic hepatitis, and healthy carriers (Dhawan 1993). In addition, it is used in liver and stomach medicines and prescribed for treatment of respiratory and allergic diseases (Sarin 2008). Consequently, *P. kurroa* is among the top 15 traded plant species in India in terms of economic value (Ved & Goraya 2008).

In recent times exploitation of *P. kurroa* has become a flourishing business for illegal collectors. Uncontrolled exploitation, along with other factors including habitat destruction, overgrazing and increasing tourism activities in habitats, are responsible for the dwindling of wild populations, which provide over 90% of the market demand of *P. kurroa*. Obtaining 1kg of dry weight *P. kurroa* requires uprooting 300 to 400 individual plants (Uniyal et al. 2009). Indiscriminate, unscientific harvesting and lack of organized cultivation of the plant has threatened its status in the wild, and it is listed as an endangered species by IUCN (Nayar & Shastri 1990). The conservation assessment and management prioritization (CAMP 2003) workshop on medicinal plants of northwestern Himalayan states held in Shimla also declared *P. kurroa* as endangered in Jammu & Kashmir and Himachal Pradesh, while its status in Uttarakhand was declared as critically endangered. In the recent past, the consumption of *P. kurroa* in different sectors in India was estimated at 415 metric ton/year (Ved & Goraya 2008). In 1980, 1.47 metric tons of *P. kurroa* were extracted from Himachal Pradesh, and this figure was 10 times higher in 1990 (Sharma 1995). A similar pattern was reported from the Gori Valley, Uttarakhand, where about 5 metric tons of *P. kurroa* was extracted by 12 villages in 2001 (Virdi 2004)

The species is being collected from almost all the alpine meadows of the state for personal and commercial use; however, information concerning species distribution and availability across meadows is limited. Identification of suitable habitats for the reintroduction of species is the next logical step in conservation efforts. Thus the present study was designed to address i) the status of *P. kurroa* natural populations and ii) the distribution of this species in the Kumaun Himalaya.

Image 1. ***Picrorhiza kurroa***

MATERIAL AND METHODS

Study area

This study was undertaken in the alpine region of the Kumaun Himalaya, part of the central Indian Himalayan region (IHR), a major habitat of glacial and non-glacial herbs above 3,000m. The area lies between 29.716–30.816N latitude and 79.716–81.083E longitude, and

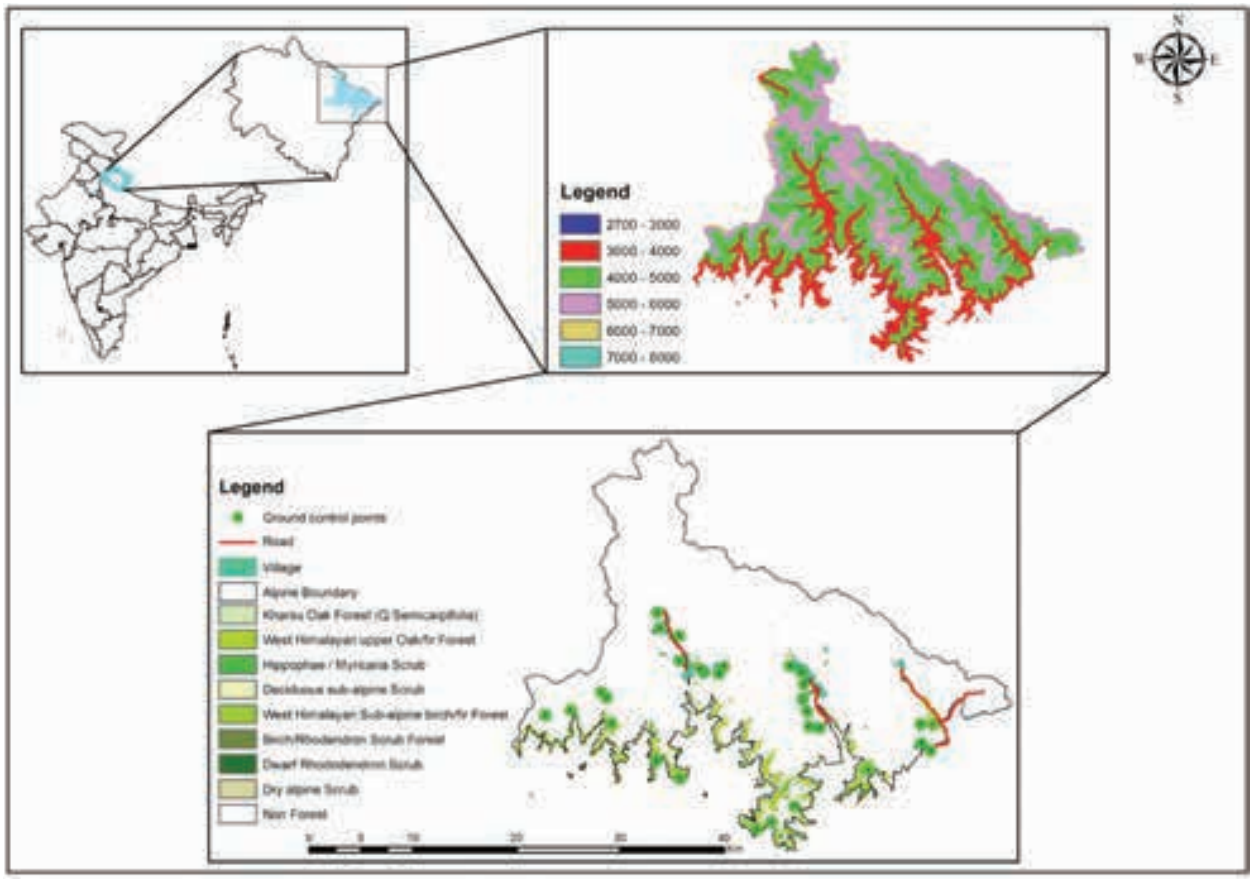

Figure 1. Study area geographical characteristic.

forms an interior most region. It is bounded by Chamoli district on the west, Tibet on the north, Nepal on the east, and Almora on the south. The total area covered between 3,000 to 5,300 m altitude is 4,617km^2. For the present study about 30 alpine meadows were surveyed. Major vegetation, road, village, altitude, and sample points are illustrated in Figure 1. These sites are under heavy snow cover for 4 to 6 months during winter, and maximum daytime air temperature reaches 25°C during the summer, followed by nearly freezing temperatures at night. Six major vegetation formations occur in the alpine region of Uttarakhand: tall forbs, short forbs or mixed herbaceous formations, matted shrubs/shrubberies, Danthonia grasslands, Kobresia sedge meadow, and cushioned vegetation (Rawat 2005). The maximum area is represented by Danthonia grassland (252.3km^2), followed by herbaceous meadows (159.3km^2) (Padalia et al. 2018). The region has nearly 40 small and large glaciers and many high-altitude lakes. Pindari, Gori, Kali, Dhauli, and Ramganga are rivers of glacial origin of this region, which harbours flora that are quite different from the flora of other areas.

Methods

Fieldwork in the alpine region is conducted from June to September, when most of the area is snow-free and plant blooming allows for easy identification. Intensive field surveys were conducted in 30 alpine meadows during 2016–19. Representative populations were found in 15 meadows, and where sizes were estimated using the rapid mapping exercise (RME) technique. Transects 500m long having 10 plots (5m circle) at every 50m interval were laid to assess major habitat types. Within each 5m circular plot, four quadrats of 1×1 m in north, east, west, and south (NEWS) directions were laid to assess the population of *P. kurroa* (Figure 2). About 30 to 40 plots were laid in each site where *P. kurroa* has been recorded.

Occurrence data and environmental variables

About (29) well distributed primary and secondary occurrence records of *Picrorhiza kurroa* were collected through field surveys and literature surveys (viz., herbarium survey of Forest Research Institute (DD) Dehradun, Botanical Survey of India (BSD), Kumaun

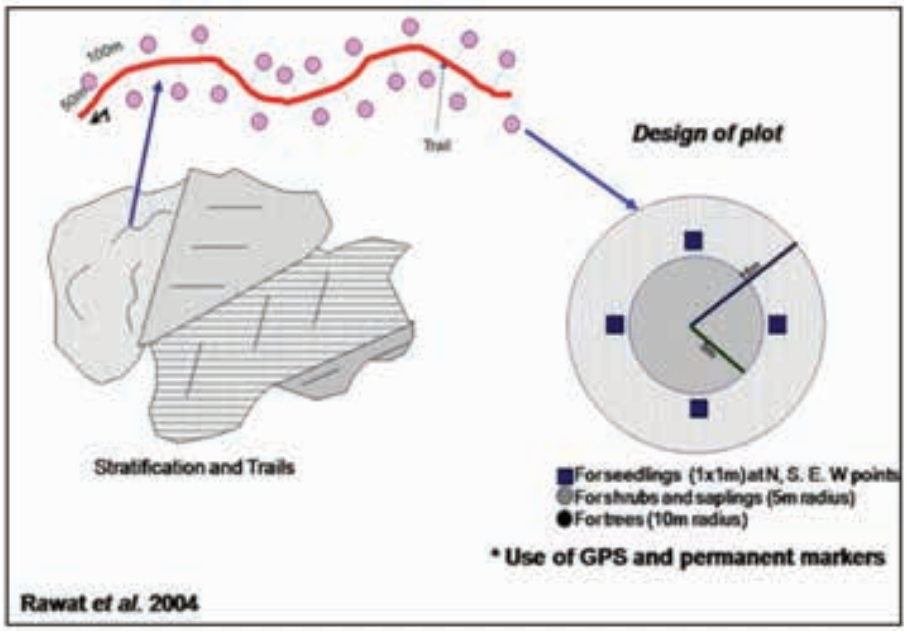

Figure 2. Rapid mapping exercise technique for estimation of MAPs (Rawat et al. 2004).

University Nainital (KU), Wildlife Institute of India (WII), and Regional Ayurvedic Research Institute (RARI) Thapla, Ranikhet), and from published literature.

The environmental variables used in this study were 25 predictors, 19 of them (bio layers) downloaded from the WorldClim v1.4 dataset at resolution of 2.5 arc-minutes (http://www. worldclim.org/bioclim). To find out the habitat suitability of the species, we used variables that included digital elevation model (DEM), slope, aspect, Euclidean distance from drainage, forest type and degradation (camping site), along with bioclimatic variables. Layers were rescaled at 1km spatial resolution (30 arc-second).

Species distribution modelling

We used a maximum entropy model (MaxEnt version 3.3.3; Phillips et al. 2006) and pixel dimension of 250×250 m grid cell, as it performs better with small sample sizes relative to other methods (Elith et al. 2006; Pearson et al. 2007). MaxEnt (Phillips et al. 2006) uses presence only data to predict the distribution of a species based on the theory of maximum entropy. The program attempts to estimate a probability distribution of species occurrence that is closest to uniform while still subject to environmental constraints (Elith et al. 2011). The maximum number of background points was 10,000. Linear or quadratic or product, categorical threshold and hinge features were used with the values 0.050, 0.250, 1.000, and 0.500, respectively. To reduce model overfitting and over-prediction, regularization multiplier value was set to 0.1 (Phillips et al. 2004) with 5,000 iterations and the rest of the values were kept as default (Yang et al. 2013). We selected 75% data for model training and 25% for model testing, keeping other values as default. Jackknife analyses were performed to determine variables that reduce the model reliability when omitted. Area under the receiving operator curve (AUC) were used to evaluate model performance, where AUC value ranges between 0 and 1, of which 1 indicates the ideal model (i.e., AUC value near to 1 indicate good predictive power of model). The model with the highest AUC value was considered the best performer (Swets 1988). To validate the model robustness, we executed 20 replicated model runs for the species with a threshold rule of 10 percentile training presence. In the replicated runs, we employed a cross-validation technique where samples were divided into replicate folds and each fold was used for test data. Other parameters were set to default as the program is already calibrated on a wide range of species datasets (Phillips & Dudík 2008).

RESULT AND DISCUSSION

Distribution of *P. kurroa*

Among 30 surveyed meadows of the Kumaun region, about 25 showed presence of *Picrorhiza kurroa* and 15 meadows had representative population sizes. Of the 15 populations assessed, seven were present in grassy slopes, five in *Rhododendron* forest margins, two in

Table 1. Site characteristics of the selected populations of *P. kurroa*.

Sites	Lattitude	Longitude	Altitude (m)	Slope (°)	Aspect	Habitat
Kuti	30.298636	80.751549	3000–3600	25–30	SE	Grassy slopes
Ralam	30.302094	80.263975	3200–3700	30–34	NW	*Rhododendron* forest margin
Milam	30.428777	80.167999	3000–3300	30–35	SW	Grassy slopes
Martoli	30.355871	80.213086	3400–3600	30–35	SE	Grassy slopes
Burfa	30.374958	80.189717	3100–3400	25–35	SE	Grassy slopes
Gunji	30.185613	80.863236	3200–3800	20–30	NW	Betula-Taxus forest
Panchachuli	30.218561	80.504378	3100–3300	30–38	SE	Grassy slopes
Napalchu Nala	30.175536	80.839672	3000–3200	30–40	NW	Grassy slopes
Laspa	30.291611	80.202882	3100–3200	25–40	SW	*Rhododendron* forest margin
Bilju	30.403455	80.173656	3150–3360	25–30	SW	*Juniperus* mixed forest
Dwali	30.180867	80.007178	3000–3150	25–35	SW	*Juniperus* mixed forest
Phurkia	30.214633	80.001388	3100–3200	25–30	NW	*Rhododendron* forest margin
Pindari	30.248124	80.000129	3200–3400	30–40	SE	Grassy slopes
Sunderdunga	30.191111	79.911033	3200–3800	25–30	NW	*Rhododendron* forest margin
Devikund	30.193395	79.890615	3900–4400	30–40	NW	*Rhododendron* forest margin

Juniperus mixed forest, and one in *Betula-Taxus* forest. Maximum populations were found in the northwestern aspect (6), followed by south-east (5) and south-west (4) between 3,000–3,900 m (Table 1).

Population structure and habitat preference of *P. kurroa*

In general, *Picrorhiza kurroa* mostly prefers matted/mixed shrub, herbaceous meadows and *Danthonia* grassy slope habitats. Population status across different meadows ranged 0.6–3.8 individuals/m^2 (Table 2). Of the 15 representative meadows, 13 had more than 1.0 individuals/m^2. The low density and frequency across the meadows showed low availability of this species. During the present investigation, *P. kurroa* was distributed in Laspa, Gunji, Bilju, Martoli, Ganghar, Milam, Kutti, Ralam, Johar, Panchachuli, & Napalchunala in Pithoragarh District and Devikund, Sunderdunga, Dwali, Phurkia, & Pindari in Bageshwar District. Phytosociological analysis revealed that *P. kurroa* grows gregariously in moist, rocky slopes as well as in organic rich soil. Past studies reported that moist rocky slopes and under scrub habitats of >3,600m altitudes showed highest density (Uniyal et al. 2002; Semwal et al. 2007). The maximum density was 3.8 individuals/m^2 in Panchachuli and 3.2 individuals/m^2 in Laspa, while minimum density was observed in Phurkia and Johar (0.64 individuals/m^2) areas. Low frequency and density shows that this species is rare and adapted to specific microhabitats.

Some habitat-based studies assert that *P. kurroa* has restricted and localized distribution in its native range. In alpine region of Gori Valley, its mean density was reported 3.89 individuals/m^2 having highest in moist rocky slopes (12.92 individuals/m^2) and least in grassy slopes (0.085 individuals/m^2). It is completely absent in the undulating and marsh meadows (Uniyal et al 2002). Degree of constancy (measure of omnipresence of a species in a given community) for *P. kurroa* was measured as 'often' in three sites 'mostly' in two sides and 'seldom' in 10 pockets having poor occurrence.

Habitat suitability

Habitat variables including slope, aspect, temperature, precipitation, drainage, altitude, and forest type were used along with bioclimatic variables to predict suitable sites for *P. kurroa*. Of the total geographical area of the Kumaun Himalaya, MaxEnt predicted 202km^2 as highly suitable and about 489km^2 as less suitable, and the rest not suitable (Figure 3). The threshold value training (0.91) and test (0.86) was close to 1, thereby showing the high accuracy of the model

Table 2. Phytosociological attributes of *P. kurroa* in different location.

	Location	Density (individuals/ m^2)	Frequency (%)	Abundance	A/F ratio	Degree of constancy
1.	Kutti	1.3	60	7.1	0.11	seldom
2.	Ralam	1.5	50	3.0	0.06	seldom
3.	Milam	0.6	40	1.5	0.03	seldom
4.	Martoli	2.4	50	4.8	0.09	often
5.	Burfa	1.8	30	6	0.2	often
6.	Gunji	1.8	60	3.0	0.05	seldom
7.	Panchachuli	3.8	50	7.6	0.15	mostly
8.	Napalchu Nala	1.2	50	2.4	0.04	mostly
9.	Laspa	3.2	40	9.7	0.24	often
10.	Bilju	2.4	60	4.0	0.06	seldom
11.	Dwali	1.4	60	2.3	0.03	seldom
12.	Phurkia	0.6	30	2.0	0.06	seldom
13.	Pindari	1.9	40	2.5	0.06	seldom
14.	Sunderdunga	1.8	50	3.6	0.07	seldom
15	Devikund	1.6	50	3.2	0.06	seldom

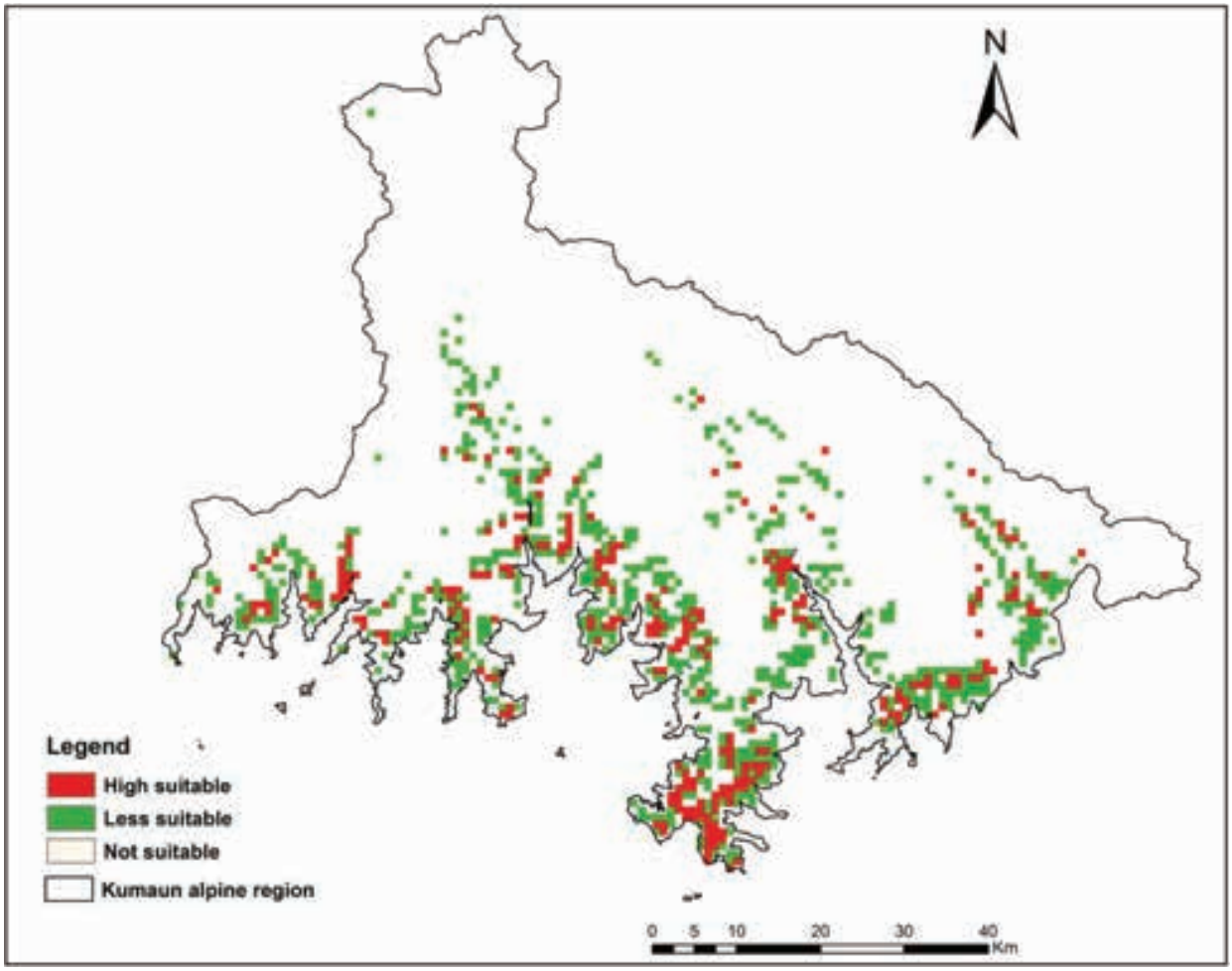

Figure 3. Habitat suitability of *Picrorhiza kurroa*

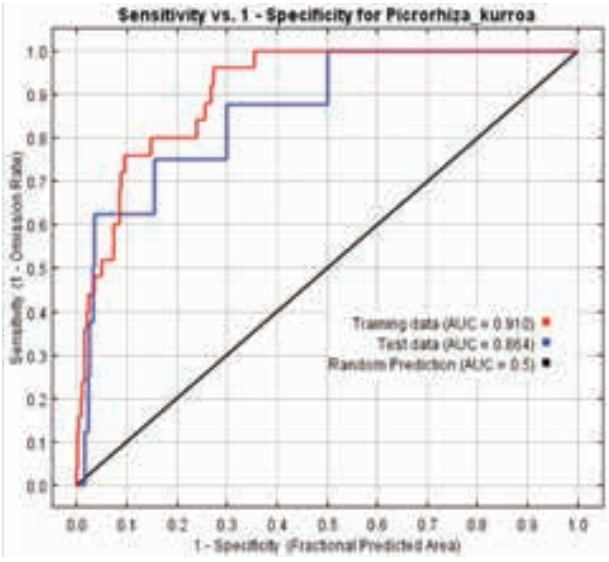

Figure 4. Receiver operating characteristic curve with area under curve (AUC).

(Figure 4).

The observed and predicted *P. kurroa* sites were mostly in forest fringes (42%) followed by grassy (30%) and rocky slopes (23%), with slopes between 15^0 and 30^0 in south-west and north-west aspects being highly preferred. Among the various environmental variables used for the prediction of distribution, mean diurnal range (Bio2 59.3%) and precipitation of driest quarter (bio17 10.9%) showed the maximum contribution, followed by aspect, forest and annual precipitation (bio12), which contributed 10.7%, 8.3%, and 4.4%, respectively. The Jackknife test showed that Bio2 (mean temperature of driest quarter) and bio17 (precipitation of driest quarter (bio 17) were the two most important predictors of *P. kurroa* when used independently (Figure 5).

Variables response to habitat suitability

Response curves show the quantitative relationship between environmental variables and the logistic probability of presence (also known as habitat suitability), and they deepen the understanding of the ecological niche of the species. The responses of 10 variables to the habitat suitability of *P. kurroa* are illustrated in Figure 6. According to the response curves, the suitable elevation range is 2,700–4,000m, which records that *P. kurroa* mainly grows at altitudes within this range on grassy slopes and *Rhodododendron campanulatum* scrub margins. Altitude usually is a key eco-factor for local plant distribution. The slopes of all sample points were lower than 38^0, with *P. kurroa* preferring 30–38^0 slope. The probability of presence was close to zero when altitude, slope, mean diurnal range (bio 2), precipitation of wettest quarter (bio 16), precipitation of driest quarter (bio 17) and mean temperature of driest quarter (bio 9) were less than 2,400m, 15^0, 17^0c, 320mm, 53mm, and -15^0c, respectively. According to the suitability grade, the suitable distribution area (probability 0.8) for *P. kurroa* requires mean diurnal range, precipitation of wettest quarter, precipitation of driest quarter, mean temperature of driest quarter to be 6–7 ^{0}C, 850–900 mm, 132–138 mm, and 30–38 ^{0}C, respectively. It was also found that forest fringe, moist rocks and *Danthonia* grassy slopes were the prefered habitats for *P. kurroa*.

DISCUSSION

In the Indian Himalayan region, a large number of studies have been carried out on ecology, systematics, and inventorisation of phytodiversity (Dhar et al. 1997; Samant et al. 2002; Joshi & Samant 2004); however, a few studies are available on population ecology and

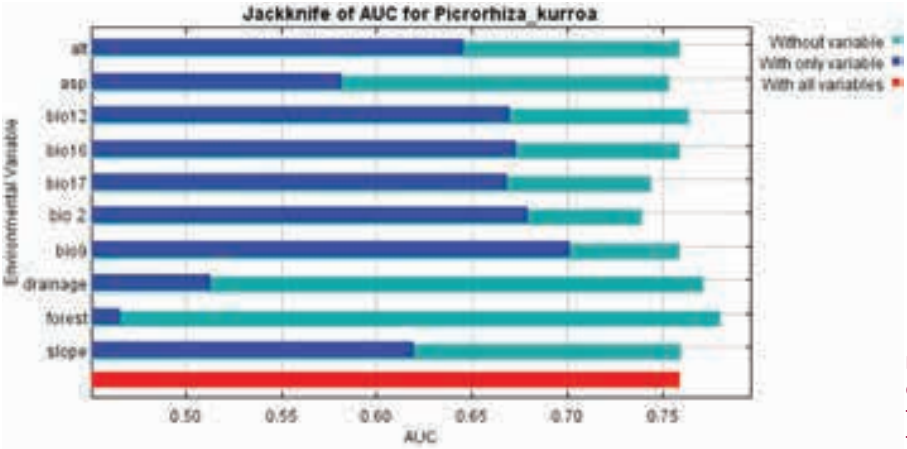

Figure 5. Result of jackknife test for evaluating the relative contribution of the predictor environmental variables to the habitat model of *P. kurroa*.

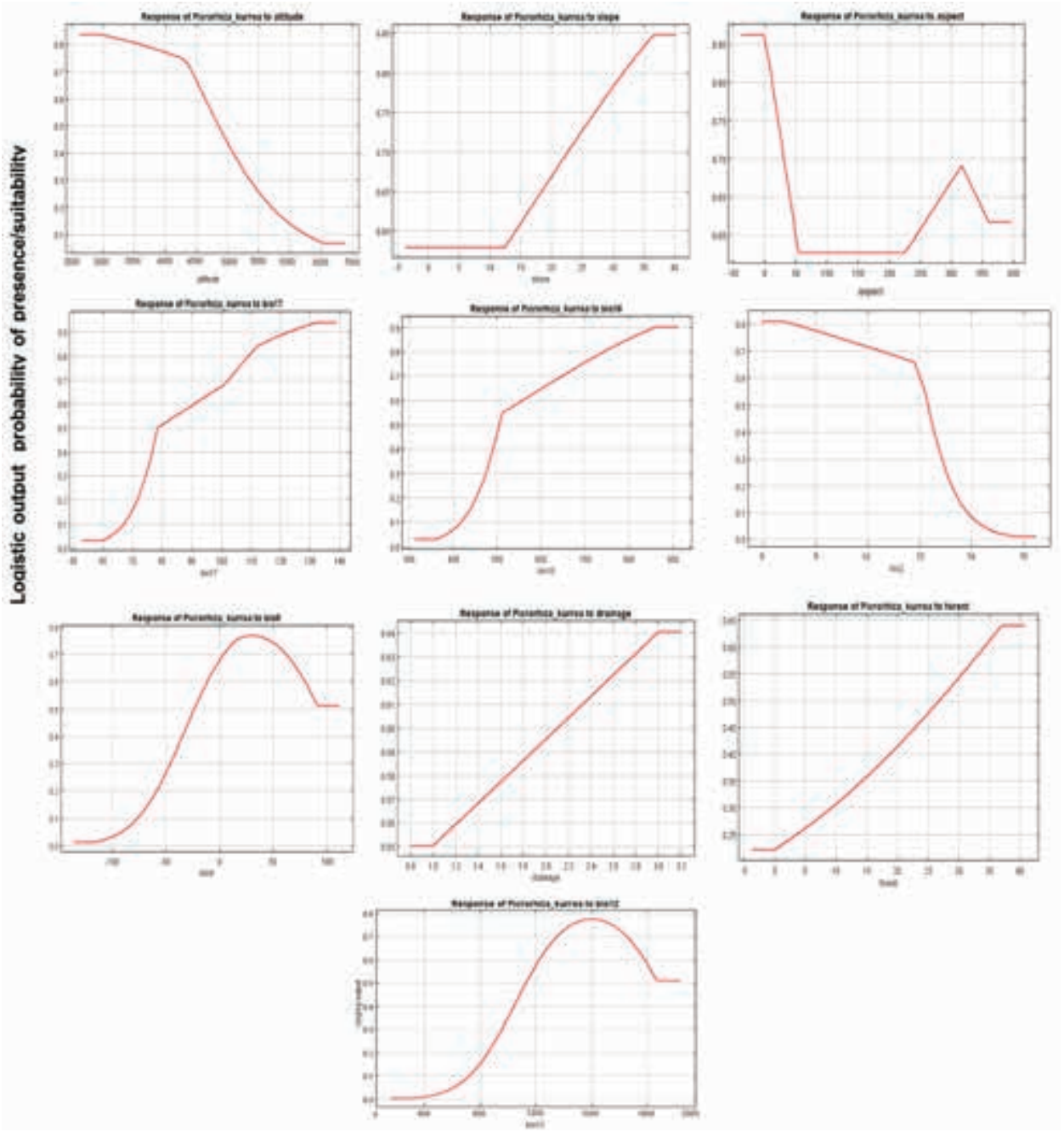

Figure 6. Response curves for environmental predictors in the species distribution model for *P. kurroa*.

ecological niche modelling (ENM) (Ray et al. 2011; Adhikari et al. 2012; Barik & Adhikari 2012; Yang et al. 2013; Samant & Lal 2015) in the region. Of the total vegetated area (3,828km^2) between 3,000–5,300 m, 202km^2 are highly suitable for *P. kurroa.* Habitats most suitable to this species are in the northwestern part of the Kumaun region, endowed with high rainfall during the rainy season. Habitat modelling illustrated that Napalchunala, Panchachuli base, Chhipla Kedar, Rongkong, Ralam, Milam, Dwali, and Pindari have prime habitats for *P. kurroa*. These areas would act as an in situ conservation area for the species and could be used for natural assisted regeneration sites. Field based surveys reveal that *P. kurroa* have more suitable habitats near the treeline of Himalayan Birch *Betula utilis* forests, *Rhododendron campanulatum*, and *Danthonia* grassy slopes. The species was mostly present in shrub canopy (40%) followed by *Danthonia* grassy slopes (35%) and

rocky slopes (25%). The species was more frequent in areas having >20° slopes and south-west and north-west. Superimposing the predicted map on high-resolution satellite images (LISS-IV and Cartosat-2 merge product) revealed that mosaic of habitats are more suitable for this species.

The abundance of the *P. kurroa* across the meadows is low. Only four meadows, viz., Panchachuli, Laspa, Bilju, and Martoli had a density over 2.0 individuals/ m^2. Overall, the highest density was recorded on moist *Danthonia* grassy slopes. Low population density may be due to overexploitation for medicinal purposes, poor regeneration, low seed germination, habitat loss, and anthropogenic pressure. The maximum numbers of populations (7) were represented by grassy slopes habitat indicating that such habitats form the best platform for the overall development of the species. The high density of species in grassy slopes and *Rhododendron* forest margin habitats indicated that such habitat is suitable for the germination of seeds and development of seedlings.

It is also observed that population of *P. kurroa* was low in sites close to shepherds' camps and high in areas where collection was negligible. Threat assessment indicates this species is being diminished day by day. Owing to various anthropogenic activities and their intensity, the species is locally common hence designated as locally common heavy pressure (LCHP). Among the habitat suitability classes, three classes, i.e., high, moderate and less suitability classes can be considered for the reintroduction (conservation) of the species. The model output result predicted that ecological niche coincides with the literature and field geographical distribution. Better population status of the species in areas of higher model thresholds such as Panchachuli, Laspa, Bilju, and Martoli revealed that these areas have suitable conditions for the persistence of species. For the in situ and ex situ conservation, mass multiplication of species through seeds and awareness and active participation of local people, community-based organizations, non-government organizations, and forest department are essentially required.

CONCLUSION

The study provides comprehensive information on population and habitat distribution of *P. kurroa.* Meagre information exists on the ecology, distribution, and population status of *P. kurroa* in the wild, and its populations and habitats are diminishing at alarming rate. *P. kurroa* has been listed among top 20 species prioritized for conservation and development keeping in view the status in the wild, sensitivity to anthropogenic impacts and its increasing demand in the market. Of the total vegetated area above 3,000m in the Kumaun, only 5.27% is highly suitable for the species; however, another 12.8% (489km^2) is less suitable, which includes meadows with excessive anthropogenic pressure and degradation. The observations on population, habitat distribution and threat status of *P. kurroa* illustrate that although suitable habitats were present in different locations, this species is restricted to very few sites with comparatively low population. Highly suitable sites less are accessible due to excessive livestock grazing and trampling and uprooting plants for medicinal purpose or marketing by local inhabitants. If immediate steps for management and regulation in collection are not taken, this species will be extinct from many localities in the near future.

Although *P. kurroa* is categorised as critically endangered, there is no management plan for conservation due to lack of related information and exploitation of species continues from the wild through unscientific manner. In nature, the species preferred moist, rocky slopes, and organic rich soil for rich populations. Therefore, for the domestication of the species, moist sites preferably north-west facing slopes would be more appropriate. Besides this, long term monitoring of *P. kurroa* is needed having specific conservation plots in the wild across meadows. Similarly, areas already reported to be rich in population of *P. kurroa* should be marked as control sites for future monitoring and repeated sampling. The strengthening of medicinal plant conservations areas established in the region would not only conserve and multiply medicinal and aromatic plants, but also will protect soil erosion and original habitats of the plants.

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COMMUNICATION

Occurrence of gilled fungi in Puducherry, India

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Abstract: Thirty-three species of gilled fungi belonging to 23 genera and 14 families were recorded from Puducherry, southern India. *Agaricaceae* were represented by eight species, followed by *Psathyrellaceae* (5), *Lyophyllaceae* & *Marasmiaceae* (3 each), *Hymenogastraceae*, *Pleurotaceae*, *Pluteaceae,* & *Polyporaceae* (2 each), and *Biannulariaceae*, *Bolbitiaceae*, *Omphalotaceae*, *Schizophyllaceae*, *Strophariaceae*, & *Tricholomataceae* (1 each). Fourteen species of agarics are new reports from Puducherry. *Chlorophyllum rhacodes*, *Lactocollybia epia*, *Leucoagaricus meleagris*, and *Schizophyllum commune* were widely distributed. Phylogenetic relationships of the abundant species *C. rhacodes*, *L. epia*, and *L. meleagris* were inferred by maximum likelihood method.

Keywords: Agarics, *Agaricaceae*, mushrooms, phylogeny, southern India, taxonomy.

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Author contributions: VK—carried out field trips to various places in Puducherry to record gilled fungi. He did the major part of morphological and microscopic characterization of gilled fungi and wrote the manuscript. SC—Ph.D. scholar carrying out research work under the supervision of Dr. Vadivelu Kumaresan helped in sampling gilled fungi and carrying out part of microscopic analysis. TSM—sequenced the ITS region of three gilled fungi and carried out phylogenetic analysis. SG—assisted in identifying and describing some of the species of agarics mentioned in the present study.

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INTRODUCTION

Gilled fungi belonging to *Agaricales* Underw. constitute ~10% of fungal species described so far (Kirk et al. 2008). It has been assumed that India hosts one-third of the global fungal taxa (Manoharachary et al. 2005) and hence there is an urgent need to document fungi in the unexplored parts of this country covering all possible habitats and seasonal variations. This will help in maintaining the germplasm of these important fungi, as well as to screen these macrofungi for their unique and versatile metabolic potential.

Gilled fungi in Puducherry have not been extensively studied. Studies on the diversity of macrofungi in adjacent areas are by Mani & Kumaresan (2009a,b). Thirty species of white-spored agarics have been reported from Puducherry (Kumaresan et al. 2011), although their identity was not confirmed by phylogenetic inferences. With the rapid deterioration of natural habitats due to human activity, it has become imperative to record these fungi before they become extinct. The study becomes even more interesting considering the fact that these basidiomata are ephemeral, especially the gilled fungi. Moreover, scientists have taken recourse to molecular techniques for identification of these poorly-studied organisms. Many Indian species are called after their North American or European lookalikes (Cannon & Kirk 2007). Sequencing the internal transcribed spacer region for as many fungi as possible from different regions will help immensely in creating or adding to the existing sequence database, to resolve the identities of species complexes and uncover new taxa.

MATERIALS AND METHODS

Basidiomata were sampled during the rainy season of 2007–2009 and 2016–2019 from different places in Puducherry, located 160 km south of Chennai on the southeastern coast of India. The area has a tropical climate and receives a mean annual rainfall of around 126 cm during the north-east monsoon in the months of October–December. During collection, photographs of fresh specimens were taken and morphological characters of fresh basidiomata such as colour (Kornerup & Wanscher 1978), size, and gill attachment were recorded in the field (Senthilarasu & Kumaresan 2018). Dried basidiomata were sealed in zip lock polythene covers after labeling for further microscopic studies. Samples are maintained in the mushroom herbarium collection in the Department of Botany, Kanchi Mamunivar Government Institute for Postgraduate Studies and Research, Puducherry, India.

Microscopic examination

Thin hand-made sections of the pileus and gills were taken and revived in 5–10 % KOH and stained with phloxine (1 %). Microscopic features were recorded following Largent (1977). Approximately, 30 basidiospores sections were measured, excluding the apiculus. The spore quotient (Q) was obtained by dividing the mean length by the mean width in profile view.

DNA extraction and PCR amplification

Few nuclear ribosomal internal transcribed spacer sequences are available for a majority of the species observed here, thus we isolated whole genomic DNA and amplified the ITS sequence to compare it with available sequences in the NCBI database.

The pure fungal culture of *Leucoagaricus meleagris* was inoculated onto potato dextrose agar and grown for 10 days at 26 °C, and the mycelia were processed for genomic DNA isolation (Paranetharan et al. 2018). Dried basidiomata of *Chlorophyllum rhacodes* and *Lactocollybia epia* were processed for genomic DNA isolation following the method of Gardes & Bruns (1993). Using the fungal specific primers ITS1F (CTTGGTCATTTAGAGGAAGTAA) and ITS4B (CAGGAGACTTGTACACGGTCCAG) (Gardes & Bruns 1993), a PCR reaction was performed to amplify the internal transcribed spacer (ITS) region. The PCR mix consisted of PCR buffer, forward and reverse primers (10 µM each), dNTPs (4 mM), Taq Polymerase (1 U), DMSO (1 %), $MgCl_2$ (25 mM) and genomic DNA (10–25 ng).

The PCR amplification was performed as follows: 95 ºC for 10 min, 30 cycles of 95 ºC for 30 s, 55 ºC for 30 s and 72 ºC for 60 s; and 72 ºC for 10 min. The PCR products were purified and sequenced using ABI 3130 genetic analyzer using primers ITS1F and ITS4B.

Phylogenetic analyses

Sequences were compared using NCBI Blast. Sequences with significant matches were selected and aligned using ClustalW (Thompson et al. 1994), checked visually and edited as required, and evolutionary trees were inferred using the maximum likelihood approach (Kimura 1980) using MEGA v6.06 (Tamura et al. 2013). Bootstrap analysis (1,000 replicates) was performed to calculate the branch support (Felsenstein 1985).

RESULTS

A total of 33 species of gilled fungi from 23 genera in 14 families were recorded from Puducherry. Of these, eight species from four genera belonged to *Agaricaceae*, constituting the dominant family among the 14 agaric families. *Psathyrellaceae* was represented by five species from three genera, *Lyophyllaceae* by three species from one genus and *Marasmiaceae* by three species from three genera, and *Hymenogastraceae*, *Pleurotaceae*, *Pluteaceae*, and *Polyporaceae* by two species each (Table 1, Images 1–3).

Taxonomy

Agaricus endoxanthus Berk. & Broome, J. Linn. Soc., Bot. 11(no. 56): 548 (1871).

Pileus 40–90 mm diam., convex to plano-convex with broad umbo, dark brown (6E8) to henna brown (7E8) at disc, fading towards margin, pileus easily peeling off, surface dry, appressed fibrillose, margin decurved, entire. Lamellae free, crowded, reddish-brown (8D6), edge smooth. Stipe 45–100 × 5–13 mm, central, terete, broadened towards base, white, greyish-brown (5D3) near base, fleshy fibrous, hollow, surface smooth. Annulus superior, membranous, large. Basidiospores 4.5–6.0 × 3–4.5 µm, Q= 1.46, ovoid to ellipsoid, brown, thick-walled.

On ground, in groups. (PY096).

Agaricus trisulphuratus Berk., Ann. Mag. nat. Hist., Ser. 5 15: 386 (1885).

Pileus 20–30 mm diam., globoso-campanulate to convex, surface with cadmium orange (5A8) to salmon orange (6C4) with thick pulverulent veil, later fading away, margin appendiculate. Lamellae free, dark henna brown (7E8), crowded. Stipe 25–45 × 2–4 mm, terete, equal, surface below the annulus concolorous with the pileus and covered by pulverulent veil. Annulus superior, fugacious. Basidiospores 4.5–6.5 × 3–4 µm, Q= 1.53, ovoid to ellipsoid, brown, thick-walled.

On ground, solitary. (PY109).

Agrocybe manihotis Pegler, Kew Bull. 21(3): 508 (1968).

Pileus 30 mm diam., convex, greyish–orange (5B3), smooth, margin decurved, entire. Lamellae adnexed, brownish grey (5C2), crowded. Stipe 45 × 5 mm, central, concolorous with the pileus, cartilagenous, smooth. Spore-print brown. Basidiospores 10.5–12 × 6.5–7.5 µm, Q= 1.61, ellipsoid, thick-walled with truncated germ pore, brown. Pleurocystidia pyriform, 32–45 × 16–20

Table 1. Gilled fungal species recorded from Puducherry, India.

Family	Genus	Species
Agaricaceae	*Agaricus*	*Agaricus endoxanthus* Berk. & Broome
		Agaricus trisulphuratus Berk.
	Chlorophyllum	*Chlorophyllum molybdites* (G. Mey.) Massee*
		Chlorophyllum rhacodes (Vittad.) Vellinga*
	Leucoagaricus	*Leucoagaricus meleagris* (Gray) Singer
		Leucoagaricus serenus (Fr.) Bon & Boiffard*
	Leucocoprinus	*Leucocoprinus birnbaumii* (Corda) Singer*
		Leucocoprinus cepistipes (Sowerby) Pat.*
Biannulariaceae	*Macrocybe*	*Macrocybe lobayensis* (R. Heim) Pegler & Lodge
Bolbitiaceae	*Panaeolus*	*Panaeolus cyanescens* Sacc.#
Hymenogastraceae	*Gymnopilus*	*Gymnopilus subtropicus* Hesler
	Naucoria	*Naucoria conicopapillata* (Henn.) Sacc.*
Lyophyllaceae	*Termitomyces*	*Termitomyces clypeatus* R. Heim
		Termitomyces microcarpus (Berk. & Broome) R. Heim*
		Termitomyces striatus (Beeli) R. Heim*
Marasmiaceae	*Crinipellis*	*Crinipellis megalospora* Singer*
	Lactocollybia	*Lactocollybia epia* (Berk. & Broome) Pegler*#
	Tetrapyrgos	*Tetrapyrgos nigripes* (Fr.) E. Horak*
Omphalotaceae	*Marasmiellus*	*Marasmiellus confluens* (Pers.) J.S. Oliveira
Pleurotaceae	*Hohenbuehelia*	*Hohenbuehelia atrocoerulea* (Fr.) Singer*
	Pleurotus	*Pleurotus ostreatus* (Jacq.) P. Kumm.*
Pluteaceae	*Volvariella*	*Volvariella hypopithys* (Fr.) Shaffer*
		Volvariella volvacea (Bull.) Singer*
Polyporaceae	*Lentinus*	*Lentinus cladopus* Lév.*
		Lentinus squarrosulus Mont.*
Psathyrellaceae	*Coprinopsis*	*Coprinopsis lagopus* (Fr.) Redhead, Vilgalys & Moncalvo
	Parasola	*Parasola plicatilis* (Curtis) Redhead, Vilgalys & Hopple
	Psathyrella	*Psathyrella candolleana* (Fr.) Maire
		Psathyrella glaucescens Dennis
		Psathyrella obtusata (Pers.) A.H. Sm.
Schizophyllaceae	*Schizophyllum*	*Schizophyllum commune* Fr.*
Strophariaceae	*Agrocybe*	*Agrocybe manihotis* Pegler
Tricholomataceae	*Lepista*	*Lepista hyalodes* (Berk. & Broome) Pegler*#

*The species have already been recorded with brief descriptions in Kumaresan et al. (2011). The remaining species are recorded for first time from Puducherry.
#Incertae sedis.

Image 1. A—*Agaricus endoxanthus* | B—*Agaricus trisulphuratus* | C—*Gymnopilus subtropicus* | D&E—*Leucocoprinus meleagris* | F—*Marasmiellus confluens* | G—*Macrocybe lobayensis*. © Vadivelu Kumaresan.

µm, Cheilocystidia broadly clavate to cylindric, 24–30 × 8–10 µm.

On ground along the grass, solitary. (PY1746).

Coprinopsis lagopus (Fr.) Redhead, Vilgalys & Moncalvo, in Redhead, Vilgalys, Moncalvo, Johnson & Hopple, Taxon 50(1): 229 (2001).

Pileus 30–45 mm diam., plano-convex to plane, initially yellowish-brown (5D8) at the disc, becoming brown (6E8), brownish-orange (5C5, 5C4) towards margin, surface dry, margin plane, crenate, plicate-striate. Lamellae adnate, subdistant, width 3 mm, teak brown (6F5), edge smooth. Stipe 30–55 × 2–4 mm, central, terete, with slightly bulbous base (10 mm diam.), white, surface with striations and superficial pruinose scales, cartilagenous, hollow, small collar like ring at the base. Rhizomorphs present. Spore-print black. Basidiospores 9.5–12 × 5.5–7 µm, Q= 1.78, ellipsoid to elongate-ellipsoid, truncated by apical germ-pore, black, smooth.

Scattered, on ground. (PY098).

Gymnopilus subtropicus Hesler, Mycol. Mem. 3: 41 (1969).

Pileus 20–60 mm diam., convex to plane, apricot yellow (5B6) fading towards the margin to butter yellow (4A5), squamulose at the disc reddish-brown (9E8), greyish ruby (12D7) in young, surface dry, margin decurved, entire. Lamellae adnate with decurrent tooth, close, greyish-orange (5B4), gill edge smooth, lamellulae of 5 lengths, width 5 mm. Stipe 30–50 × 3–8 mm, terete, hollow, butter yellow (4A5), base hygrophanous to reddish-brown (9F8), fleshy fibrous, striate due to appressed scales. Spore-print brownish-orange. Basidiospores 5.5–8 × 4–5 µm, Q = 1.51, ellipsoid, brown, verruculose.

On palm trunk, in groups. (PY119).

Leucoagaricus meleagris (Gray) Singer, Lilloa 22: 422 (1951) [1949].

Pileus 25–35 mm diam., convex to expanded convex, broadly parabolic when young, dark brown (8F8) at the disc, white towards the margin, surface pruinose, margin decurved, entire. Lamellae free, white, crowded. Stipe 60–110 × 5–8 mm, central, terete, expanding towards the base, fleshy fibrous, smooth, solid. Annulus superior. Spore-print white. Basidiospores 6–8 × 5–6 µm, Q= 1.53, broadly ellipsoid to ellipsoid, slightly truncated with germ-pore, hyaline, dextrinoid with a thickened wall, guttulate. Pleurocystidia absent. Chielocystidia 25–45 × 10–15 µm ellipsoid to short cylindric with pronounced mucronate apex.

On decaying wood, in groups and scattered. (PY19111).

Macrocybe lobayensis (R. Heim) Pegler & Lodge, in Pegler, Lodge & Nakasone, Mycologia 90(3): 498 (1998).

Pileus 50–120 mm diam., convex, white, plane, dry, margin decurved, entire. Lamellae adnate, whitish to cream, crowded. Stipe 40–100 × 15–35 mm, central, white, fleshy fibrous, smooth, solid. Spore-print white. Basidiospores 4–6 × 3–4.5 µm, Q = 1.32, broadly ellipsoid to ellipsoid, thin-walled, hyaline.

On ground, on soil root interface, solitary. (PY19126).

Marasmiellus confluens (Pers.) J.S. Oliveira, in Oliveira, Vargas-Isla, Cabral, Rodrigues & Ishikawa, Mycol. Progr. 18(5): 734 (2019).

Pileus 15–25 mm diam., convex to plane, dry, reddish brown (9E8) at the disc, brown (6D8) towards the margin, margin decurved, striate. Lamellae adnexed, white to yellowish-white (1A2), crowded. Stipe 25–60 × 2–3 mm, central to slightly eccentric, concolorous with the pileus, terete to compressed. Spore-print white. Basidiospores 5–6.5 × 2–3 µm, Q= 2.34, elongate to cylindric, nearly fusoid, hyaline, inamyloid. Pleurocystidia absent. Chielocystidia 32–40 × 3.5–5.5 µm, cylindric to subfusoid, flexuous, often somewhat lobed and diverticulate.

On leaf litter in groups, scattered. (PY1931).

Panaeolus cyanescens Sacc., Syll. fung. (Abellini) 5: 1123 (1887).

Pileus 20–35 mm diam., convex to conico-convex, disc brownish-grey (5C3), yellowish-white (4A2) to yellowish-grey (4B2), towards margin, surface dry, smooth, becoming bluish-green on bruising, margin decurved, entire. Lamellae adnate to adnexed, close, yellowish-brown (5D8) to raw umber (5F8). Stipe 50–60 × 2–3 mm, terete, equal, yellowish white (4A2) to yellowish-grey (4B2), cartilaginous, hollow, surface superficially pruinose, bluish-green on bruising. Basidiospores 11.5–14 × 7–8.5 µm, Q = 1.65, lenticular, limoniform in face-view, elongate-ellipsoid in side view, blackish-brown, smooth apically truncated by a germ-pore.

On soil and decaying litter, in groups. (PY092).

Parasola plicatilis (Curtis) Redhead, Vilgalys & Hopple, in Redhead, Vilgalys, Moncalvo, Johnson & Hopple, Taxon 50(1): 235 (2001).

Pileus 20–25 mm diam., membranous, convex to plane, greyish-yellow (4B5) at the disc, grooves orange white (6A2), olive brown (4D8) elsewhere, surface dry,

Image 2. A—*Psathyrella obtusata* | B—*Panaeolus cyanescens* | C—*Chlorophyllum rhacodes* | D—*Crinipellis megalospora* | E—*Termitomyces clypeatus.* © Vadivelu Kumaresan.

plicate striate, margin plane, crenate. Lamellae free, brownish grey (4D2), subdistant. Stipe 85–100 × 1–2 mm, central, terete, white, cartilagenous, smooth, inserted. Basidiospores 11.5–14.5 × 8.5–10.5 µm, Q= 1.47, lenticular, ellipsoid in side view, with abaxially inclined germ-pore, black, smooth.

Solitary, on ground. (PY065).

Psathyrella candolleana (Fr.) Maire, in Maire & Werner, Mém. Soc. Sci. Nat. Maroc. 45: 112 (1937).

Pileus 20–35 mm diam., convex to broadly companulate, brown (6E8) to brownish-orange (5C4), margin appendiculate. Lamellae adnexed, dark brown (9F7), crowded. Stipe 40–70 × 3–4 mm, central, white, terete, smooth, hollow. Spore-print dark brown. Basidiospores 6–7.5 × 3.5–4.5 µm, Q= 1.69, ellipsoid to elongate ellipsoid, with a truncated end, smooth, dark brown. Pleurocystidia absent. Chielocystidia 20–30 × 7–12 µm, cylindric with rounded apex.

Image 3. A—*Leucocoprinus birnbaumii* | B—*Schizophyllum commune* | C—*Lepista hyalodes* | D—*Lentinus squarrosulus.* © Vadivelu Kumaresan.

On ground, in groups and scattered. (PY101).

Psathyrella glaucescens Dennis, Kew Bull. 15(1): 128 (1961).

Pileus 10–40 mm diam., conico-convex to convex, pale orange (5A3) to brownish-orange (6C4), margin white to light grey (1C3), surface dry, smooth, margin appendiculate. Lamellae adnate, brownish-orange (7C4) to greyish red (8C4). Stipe 30–70 × 2–4 mm, white, silky fibrillose, cartilaginous, hollow. Basidiospores 6.5–8 × 4–5 µm, Q = 1.63, ellipsoid, purplish-brown, apically truncated by a germ-pore.

On ground, in groups. (PY003).

Psathyrella obtusata (Pers.) A.H. Sm., Contr. Univ. Mich. Herb. 5: 55 (1941).

Pileus 15–40 mm diam., convex to broadly campanulate, cinnamon brown (6D6) at the disc, brownish-orange (6C4) elsewhere, dry, smooth, margin decurved, plane and uplifted, striate at extreme margin, crisped. Lamellae adnate, close, greyish-orange (6B3). Stipe 25–35 × 1–2 mm, terete, equal, white, cartilagenous, smooth, hollow, inserted. Basidiospores 6.5–8 × 5–6 µm, Q= 1.31, broadly ellipsoid to ellipsoid, truncated by an apical germ pore.

On ground, in groups and scattered. (PY108).

Termitomyces clypeatus R. Heim, Bull. Jard. bot. État Brux. 21: 207 (1951).

Pileus 40–70 mm diam., convex to expanded convex with a spiniform perforatium, broadly parabolic when young, surface dark brown (7F8) at the disc, fading towards the margin, smooth, margin decurved, entire. Lamellae adnexed to free, pinkish white (8A2), crowded. Stipe 50–60 × 8–10 mm, central, terete, expanding towards the base, fleshy fibrous, smooth, solid. Pseudorrhiza present. Spore-print pink. Basidiospores 5–7 × 3–4 µm, Q= 1.62, ellipsoid to elongate ellipsoid, hyaline, guttulate. Pleurocystidia pyriform. Chielocystidia subglobose.

On soil, solitary to scattered. (PY1878).

Phylogenetic analysis

The sequences obtained from *Chlorophyllum rhacodes, Leucoagaricus meleagris* and *Lactocollybia epia* have been deposted in GenBank with the accession numbers MT229200, MT229202, KU320581, respectively. We constructed maximum likelihood trees to compare our sequences to understand their phylogenetic relationship with related sequences from the database (Figures 1–3). The phylogenetic tree generated using ITS dataset for *C. rhacodes* and related species included 28 nucleotide sequences. The tree with the highest likelihood (-2549.8398) is depicted (Figure 1). For constructing the tree, all positions with less than 95 % site coverage were eliminated and the final dataset included 537 positions. The ITS sequence of *C. rhacodes* from this study (MT229200) was placed in the same subclade containing sequence belonging to ITS sequence of *C. rhacodes* isolated from Gorakhpur, India (MH820354) with 100 % support. The maximum likelihood tree generated for ITS sequence of *L. meleagris* and its other related species included 17 nucleotide sequences. The tree with the highest likelihood (-1609.0537) is depicted (Figure 2). The final dataset included 604 positions after removing all positions with less than 95 % site coverage. Our isolate (MT229202) clustered in the same subclade with other *L. meleagris* isolate (GQ249888) from Rajasthan, India with 100 % bootstrap support. For *L. epia* and its related isolates, the maximum likelihood tree generated included 20 nucleotide sequences and the tree with the highest likelihood (-3410.7721) is shown (Figure 3). The final dataset included 412 positions after removing all positions with less than 95 % site coverage. Our isolate (KU320581) clustered together with *L. epia* (MN523272), an isolate obtained from China, and showed 100 % bootstrap support.

DISCUSSION

Puducherry does not have any major forest, but there are patches of tropical dry evergreen forest and small areas of sacred groves and mangroves (Ponnuchamy et al. 2013). Therefore, not much litter deposition occurs to create conditions favourable for litter fungi. Studies on the occurrence of agarics in Puducherry resulted in recording more gilled fungi from soil as substrate including *A. endoxanthus*, *A. trisulphuratus*, *C. molybdites*, *C. rhacodes*, *L. serenus*, *P. cyanescens*, three species of *Termitomyces*, *V. hypopithys*, *C. lagopus*, *P. plicatilis*, three species of *Psathyrella*, *A. manihotis*, *L. hyalodes*, and *M. lobayensis*. Most of the dark-spored species recorded in the present study were reported by Natarajan & Raman (1983) in tropical dry evergreen forest areas. This shows that forest type plays an important role in determining agaric species composition (Küffer& Senn-Irlet 2005). The 10 dark-spored species along with four white-spored ones recorded in the present study are reported for the first time from Puducherry (Table 1). Among the three species of *Psathyrella* sampled in the present study, *P. candolleana* is known to be widely distributed (Manjula 1983; Natarajan et al. 2005; Farook et al. 2013; Amandeep et al. 2015a). Interestingly, a total of 53 species of *Psathyrella* have been recorded from India (Amandeep et al. 2015a); however, *P. glaucescens* and *P. obtusata* recorded in the present study have so far not been reported from southern India. Similarly, the genus *Termitomyces,* one of the mushrooms of tribal importance (Varghese et al. 2010), was represented by three species, of which *T. microcarpus* has been reported widely (Karun & Sridhar 2013).

Vellinga (2002) based on similarities in morphology and molecular studies transferred a few species previously placed in *Macrolepiota* Singer or *Lepiota* (Pers.) Gray, into *Chlorophyllum*. Most of the *Chlorophyllum* species occur in arid habitats in subtropical to tropical regions (Ge et al. 2018). In India, *C. rhacodes* is known to be widely distributed and recorded as *Macrolepiota rhacodes* earlier (Manjula 1983; Amandeep et al. 2015b). We found *C. rhacodes* to occur in a number of places in Puducherry and the identity of the species was confirmed through ITS sequence analysis by constructing maximum likelihood based phylogenetic tree (Figure 1). Interestingly, phylogenetic analysis of ITS sequences from two species which occurred widely in Puducherry showed that *L. meleagris* (Syn: *Leucocoprinus meleagris*) (Figure 2) clustered with *L. meleagris* reported from Rajasthan, India while *L. epia* (Figure 3) formed a tight cluster with *L. epia* reported earlier from China.

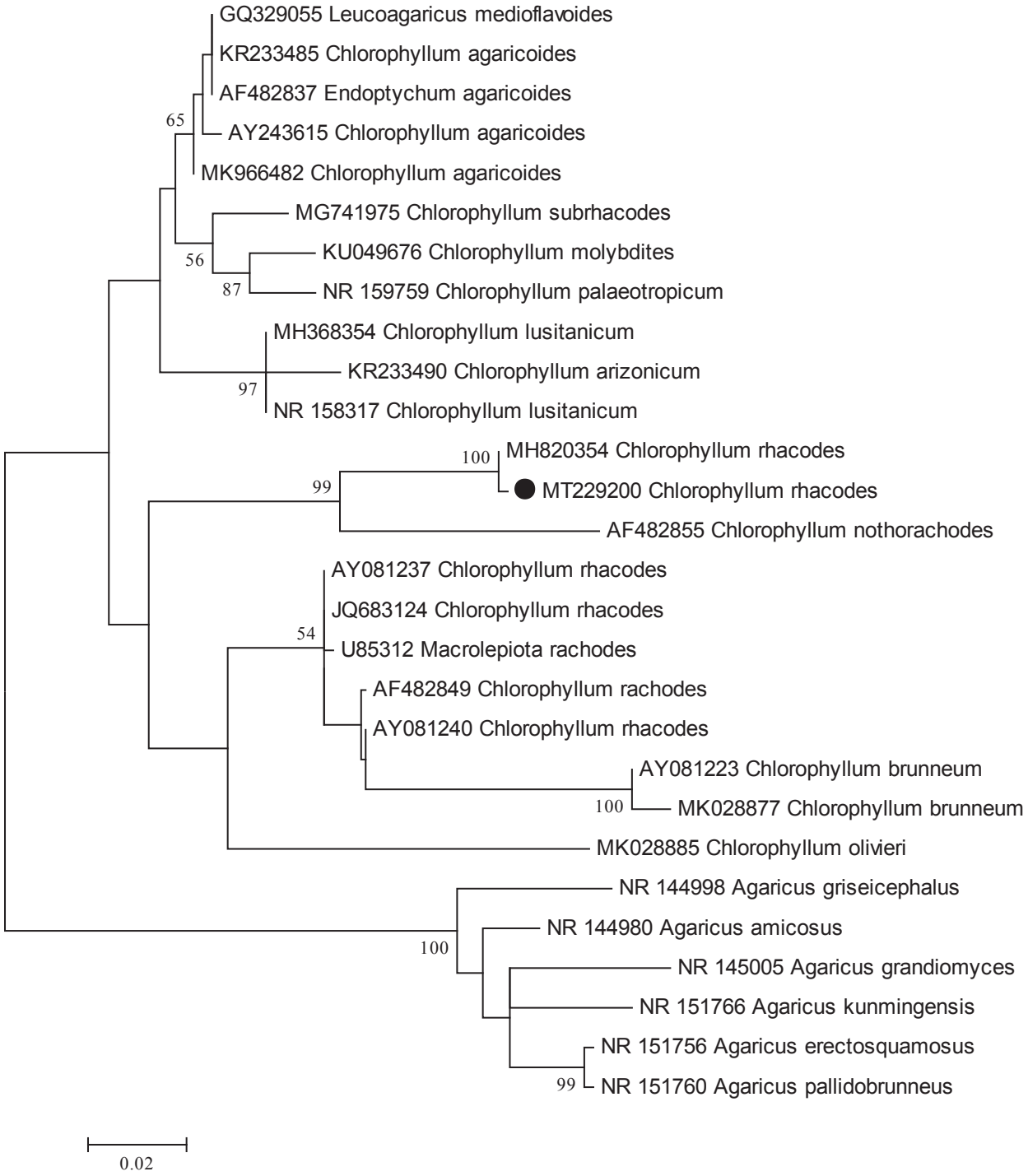

Figure 1. Phylogenetic relationship of *Chlorophyllum rhacodes* (MT229200) inferred from ITS sequences analysis by maximum likelihood method.

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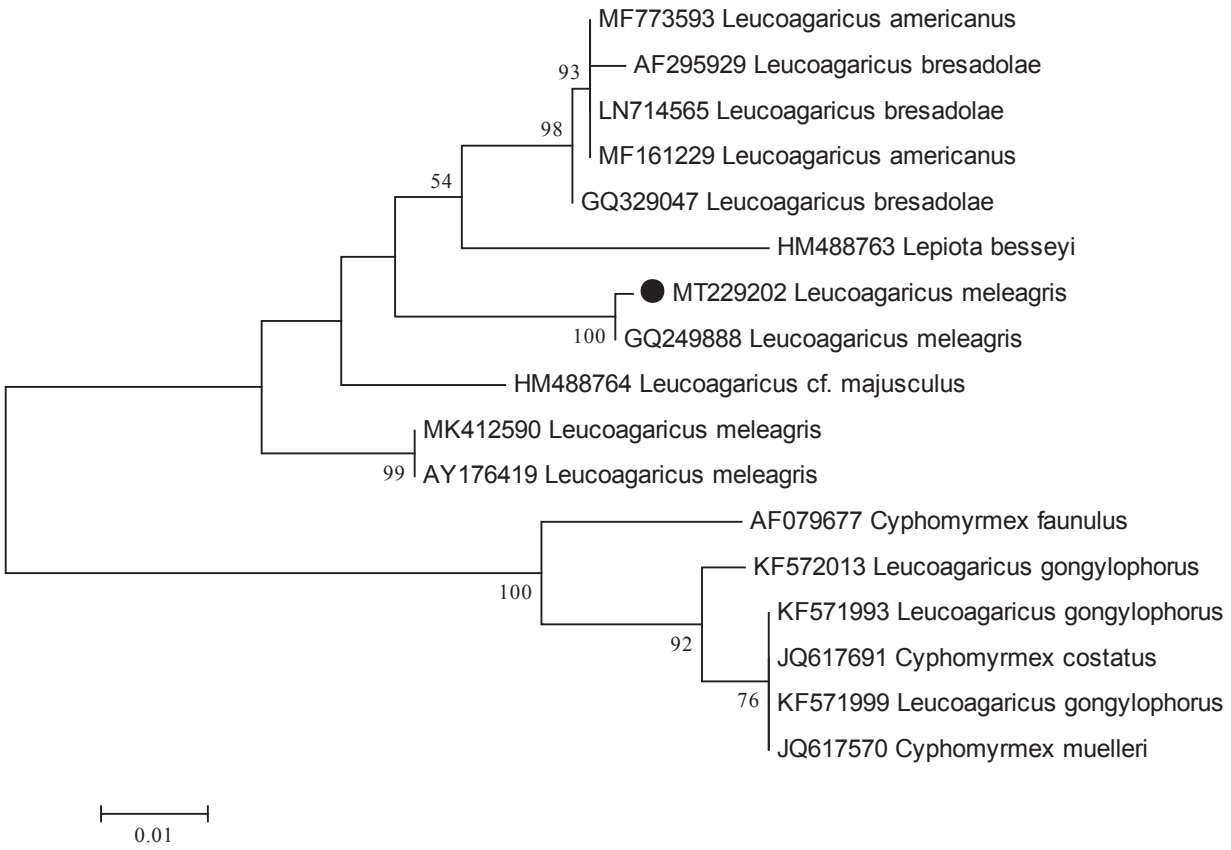

Figure 2. Phylogenetic relationship of *Leucoagaricus meleagris* (MT229202) inferred from ITS sequences analysis by maximum likelihood method.

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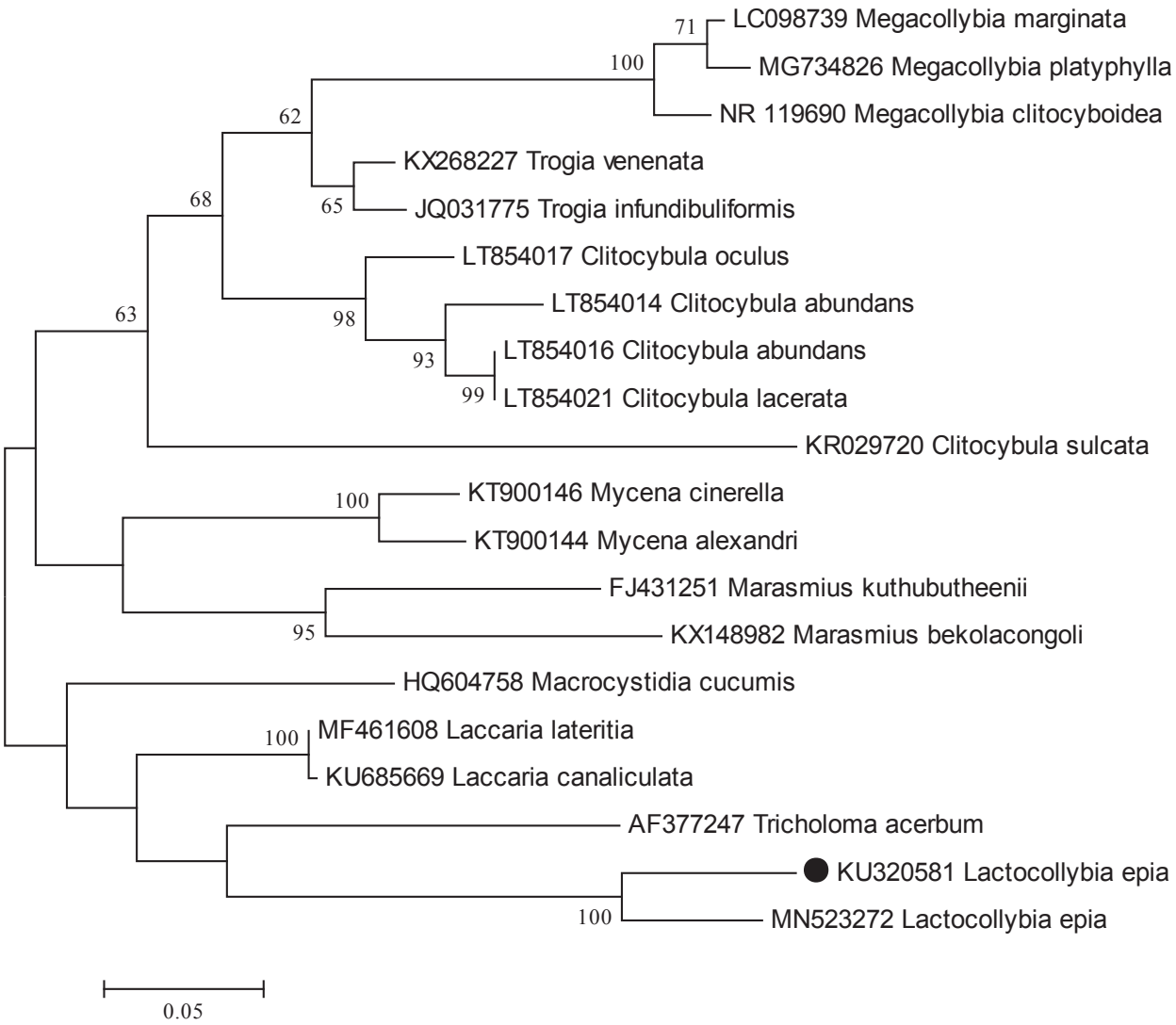

Figure 3. Phylogenetic relationship of *Lactocollybia epia* (KU320581) inferred from ITS sequences analysis by maximum liklehood method.

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SHORT COMMUNICATION

First photographic evidence and distribution of the Indian Pangolin *Manis crassicaudata* (Mammalia: Pholidota: Manidae) in Sariska Tiger Reserve, Rajasthan, India

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Abstract: The Indian Pangolin, although considered to be widely distributed due to its elusive nature and low detection probability its status and distribution records are very limited. Rampant hunting for local consumption, and illegal wildlife trade for medicinal and ornamental purposes has pushed the species towards serious decline. Herein, we report the first photographic records of the Indian Pangolin in Sariska Tiger Reserve (STR), Rajasthan, India. During our camera trapping study from June 2018 to April 2019, out of 29,220 camera trapping nights the species was recorded on four occasions, at two different locations in STR. The species was recorded in the open forest areas near natural water bodies situated in the middle of dense *Anogeissus pendula* forests.

Keywords: Endangered, illegal wildlife trade, camera trap.

The order Pholidota is represented by eight species in a single family Manidae distributed from Africa to Asia. Out of eight, two species occur in India—the Indian Pangolin *Manis crassicaudata* (E. Geoffroy, 1803) is widely distributed across most parts of the country starting from the southern part of the Himalaya, also in southern Nepal, Bangladesh, Pakistan, and Sri Lanka (Tikader 1983; Srinivasulu & Srinivasulu 2012; Mahmood et al. 2020); and the Chinese Pangolin *Manis pentadactyla* is mainly distributed across the northeastern states of the country and Nepal (Srinivasulu & Srinivasulu 2012; Challender et al. 2019). The two are morphologically similar however they can be differentiated based on the size of the scales, the Indian pangolin's scales are relatively larger than those of the Chinese Pangolin; rows of scales, Indian Pangolin have scales 11–13 rows across the back while Chinese Pangolin have 15–18 rows across the back (Pocock 1924). Indian Pangolins are quite adaptive to modified habitats having abundant prey and less exploitation pressure (Mahmood et al. 2020). The Indian Pangolin is nocturnal and rests in burrows during the daytime. Two types of burrows have been reported for Indian Pangolins, i.e., feeding burrows and living burrows (Mahmood et al. 2020). It uses its long protrusible and glutinous tongue to predate on ants and termites; consuming the eggs, young and adults of ants and termites, also ingests grit, sand and small stones that

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aid mastication (Prater 2005). Thus, the species plays an important ecological role by consuming termites which are a serious insect pest for agricultural crops and buildings (Roberts 1997). Indian Pangolins are typically solitary in nature, except during the mating and rearing of the young ones; It is believed that scent markings by males using urine, scat or anal glands are the means to maintain territory and social relations (Mahmood et al. 2020). The species inhabits wide varieties of habitat and recorded from Indian subcontinent in both forested and non-forest areas (Roberts 1977; Mahmood et al. 2020). Pangolins occurs in very low densities, few available studies estimating densities for various species of Pangolins suggests density of 0.0001 individual per km^2 for the Indian Pangolin, 0.001 individuals per km^2 for the Chinese Pangolin and 0.8 individuals per km^2 for the White-bellied Pangolin *Phataginus tricuspis* in Africa (Wu et al. 2004; Akpona et al. 2008; Mahmood et al. 2014, 2018).

The Indian Pangolin is protected under Appendix I of the Convention on International Trade in Endangered Species (CITES) and Schedule I species in the Wildlife (Protection) Act 1972, it is also listed as 'Endangered' in the IUCN Red List of Threatened Species due to its rapid decline in their numbers (Mahmood et al. 2020). Despite being protected under many regimes of the law, the population of this species is declining rapidly; mainly because of hunting for local use as meat, for traditional medicines and rampant illegal international trade for medicinal and ornamental purposes (Mahmood et al. 2012; Mohapatra et al. 2015). The scales of the species are used as a whole, or in powdered form in the preparation of traditional medicines in southeastern Asia, mainly China and Vietnam (Baillie et al. 2014; Mohapatra et al. 2015; Challender & Waterman 2017; Mahmood et al. 2019). In India, hunting and illegal trade of 119 pangolin seizures were recorded from year 2009 to 2018 and an estimated 7,500 individuals were killed (Kumar et al. 2020). Additionally, the Indian Pangolins in their habitat were killed due to the belief that they dig up graves and pull out the buried dead bodies. In addition, farmers kill the animal allegedly for damaging their crops and agricultural lands by digging the burrows (Mahmood et al. 2018).

In Rajasthan, the pangolin was once believed to be widely distributed but now it has become rare (Sharma et al. 2003). The species is recorded from Ajmer, Bikaner, Churu, and Nagaur districts in the state (Sharma et al. 2003; Dookia & Jakher 2004). It is also reported in three protected areas in the state namely Sajjangarh Wildlife Sanctuary, Mukundra Hills Tiger Reserve and Keoladeo National Park (Bhatnagar et al. 2013; Latafat & Sadhu 2016; Singh et al. 2017); one individual was rescued in Dhani Talai area of Pratapgarh forests in southern Rajasthan in 2007.

Study Area

The Sariska Tiger Reserve (STR) is situated in the Aravalli Hills in Alwar District of the Indian State of Rajasthan between 76.241°–76.545°N & 27.095°–27.648°E. The climate is subtropical, with distinct summer, monsoon and winter seasons; temperature ranges 2–47 °C with an average rainfall of 621 mm (Shekhawat 2015). The total area of the reserve is 1,213.31 km^2, with 881 km^2 critical tiger habitat (CTH) and 332 km^2 buffer area (Shekhawat 2015). In STR the altitude varies 240–777 m rugged terrain, numerous narrow to large valleys, and plateaus are main characteristic feature of habitat; Kankwari (524 m) and Kiraska (592 m) are two main plateaus. In vastly scattered forest has various geological formations and soil depth varies from few centimetres on hill slopes to 1 m in valleys (Yadav & Gupta 2006). The vegetation is tropical dry deciduous forest (Champion & Seth 1968) with Dhonk *Anogeissus pendula* as the dominant tree species, other species include *Butea monosperma*, *Boswellia serrata* and *Ziziphus mauritiana*. Apart from reintroduced Tigers *Panthera tigris*, Leopard *P. pardus*, Striped Hyena *Hyaena hyaena*, Jackal *Canis aureus*, and the Jungle Cat *Felis chaus* are the major carnivores in the reserve; while Chital *Axis axis*, Sambar *Rusa unicolor*, Nilgai *Boselaphus tragocamelus*, and Wild Boar *Sus scrofa* are major prey species (Shankar et al. 2010). STR is subjected to an extensive anthropogenic pressure, as 2,254 families reside in 26 villages situated in the area (Shekhawat 2015). In addition to that very high pilgrimage inside the reserve, habitat fragmentation due to state highways passing through the STR, increasing human-wildlife interactions and low staff strength for law enforcement are other major problems in the reserve (Bhardwaj 2018).

Materials and methods

This record was obtained as part of a camera trapping exercise that was being undertaken by the authors for monitoring of tigers in STR in three different phases. For camera trapping, the STR was divided into 440 grids of 2 km^2 each, the grids are equally distributed into two blocks (north block and south block) having 220 grids each covering an area of 440 km^2 for management purpose. Among all, 84 grids, distributed randomly among both the blocks, were identified and used as

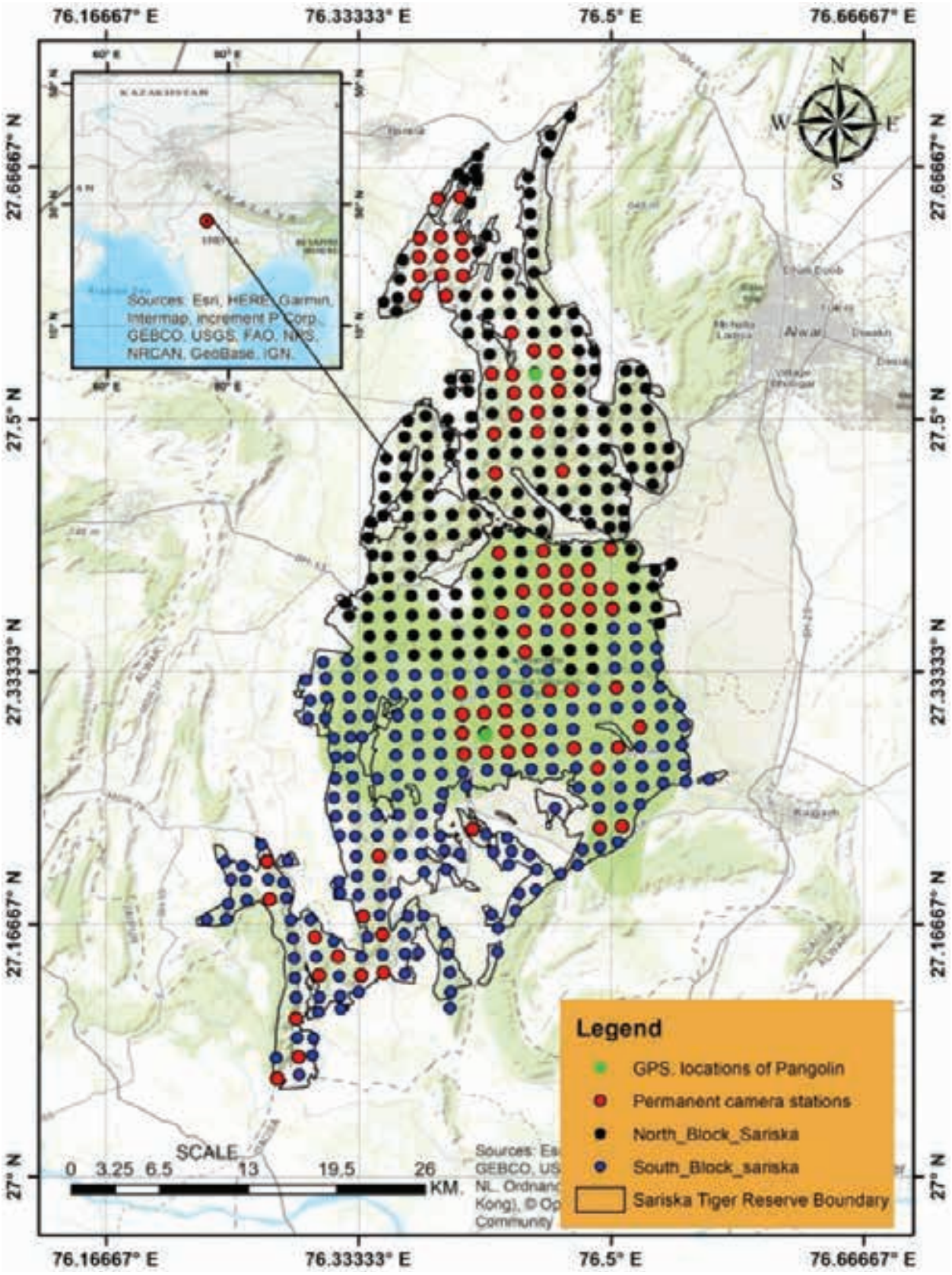

Image 1. GPS locations (shown as green dot) of Indian Pangolin camera trap captures in Sariska Tiger Reserve.

permanent camera trap stations (Image 1). The details of camera trap study is provided in Table 1. Camera traps were deployed in each block with at least one pair of camera deployed in each grid. Cuddeback 1279 20 Mega-pixel trail cameras were used for the exercise. The camera traps were deployed 40–50 cm above ground at a distance of 5–6 m on both sides from the centre of the trail. The delay between subsequent photographs was kept at 5 seconds so that young ones with mother don't get missed. Cameras were operated on a 24-hour basis. All the cameras were regularly checked in the field for proper functioning and status of the batteries. Geo coordinates of the location were recorded using handheld GPS (Garmin eTrex 20x) device set to datum WGS 84.

Results

The Indian Pangolin was recorded on four occasions at two different locations from an effort of 29,220 trap nights. Three occasions of the four was in a single camera trap location in Jahaj beat of Tehla range (27.286°N, 76.418°E) (Images 1–3), which was located in a valley near a water body. The observed habitat of the camera trap location was undulating with moderately dense vegetation *Zizyphus mauritiana* and *Butea monosperma* vegetation in the valley and dense undisturbed *Anogeissus pendula* forest on the upper regions. We also recorded one active burrow in the area based on fresh signs of digging and another inactive burrow (Image7). The burrows were deeper, the inactive burrow had a depth of 1.6 m while the active burrow was 2.8 m deep. Both the burrows had round openings. The second site of Indian Pangolin capture location was in Bija forest area near Panidhal Village (27.524° N 76.440° E).

In addition, one Indian Pangolin was observed in a moderately dense *Anogeissus* forest on a small hillock in Loj Beat of Talvriksh range during the morning hours on 29 August 2019 (Image 6). It tried to hide itself among the shrubs sensing the presence of humans in close vicinity and ultimately it disappeared into a thicket. All the camera trap images of Indian Pangolins were captured during the late night hours from 2348 h to 0219 h that demonstrates the fact that the species is active in

Image 2. Camera trap image of Indian Pangolin in Beat Jahaj, Tehla.

Image 3. Camera trap image of Indian Pangolin in Beat Jahaj, Tehla.

Image 4. Camera trap image of Indian Pangolin in Beat Jahaj, Tehla.

Table 1. Details of camera trapping survey design used in the study.

Period of Survey session	Extent of study area	Survey effort
01.vi.2018 to 30.xi.2018	84 grids (2km^2) permanent camera trap locations in both north and south block	10,080 camera trap nights
17.xii.2018 to 16.i.2019	220 grids (2km^2) of south block	6,820 camera trap nights
04.ii.2019 to 01.iv.2019	220 grids (2km^2) of north block	12,320 camera trap nights

Image 5. Camera trap image of Indian Pangolin in Loj Beat, Talvriksh.

Image 6. Image clicked through mobile phone of Indian Pangolin, in Beat Loj, Talvriksha. © Vinod Dulariya

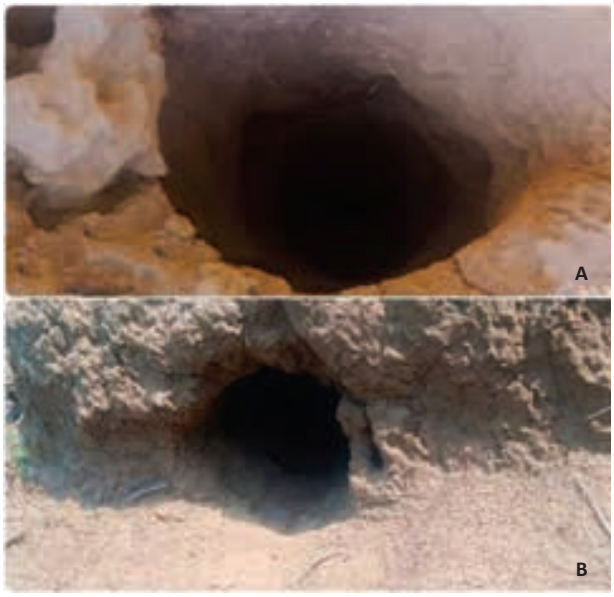

Image 7. Living burrows of Indian Pangolin: A—active burrow | B—inactive burrow in beat Jahaj, Tehla. © Rajesh Kumar

night except for one individual which was observed in the morning.

Discussion

Despite being one of the most traded species throughout the globe, very little is known about the distribution and current status of the pangolin in most of its range including Rajasthan. This can be attributed to its elusive nature and low density, as evident from the study that the species was captured only four times out of 29,920 camera nights. STR is one of the most researched protected areas (Bhardwaj 2018), but there are no published records barring a single mention in text on Indian Pangolin in the STR (Bhardwaj 2018). The camera trap pictures of the Indian Pangolin confirm its presence in the STR and adds to its biological diversity. Further, this will aid in formulating robust strategies for the conservation of the species in STR. Although the effort was intensive, the cameras were mainly installed on trails and areas for capturing the big cats, as big cats have larger home ranges and they prefer regular trails and paths for walking to avoid injuries, but the same cannot be assumed for the smaller vertebrates like the Indian Pangolin so a little bias in less detection of pangolin during the study cannot be ruled out. Since the species inhabits wide varieties of habitats and outside protected areas (Mahmood et al. 2020), the comprehensive study in STR as well as adjoining areas on the ecological aspects and population dynamics of the species would give more insight on the Indian Pangolin. The measures like creating awareness among the local people and frontline staff, including local communities to protect the Indian Pangolin from traditional hunting would help in conserving the species.

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Population and conservation threats to the Greater Flamingos *Phoenicopterus roseus* (Aves: Phoenicopteriformes: Phoenicopteridae) at Basai Wetland and Najafgarh Jheel Bird Sanctuary, Haryana, India

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Abstract: Greater Flamingos are the largest and most widespread, among other species of Phoenicopteridae. This study documents the population structure and conservation threats affecting the population and habitat of the flamingos at Najafgarh Jheel Bird Sanctuary and Basai wetland in Haryana, India. The study areas were surveyed monthly between May 2019 to February 2020 at regular intervals. A Nikon 8 X 40 field binoculars and a Nikon SX60 camera were used to observe flocks of *P. roseus*. A total of 65 flocks of flamingo were observed, and 6,768 individuals were counted using point counts method. Najafgarh Jheel Bird Sanctuary holds a major proportion of their population comprising about 91.78 % and Basai wetland holds about 8.21 % of their population, while 52.46 % of the total population were classified as adults, and 47.53 % were juveniles (sub-adults). Habitat fragmentation resulting from construction of roads is one of the major threats, while overgrowth of water hyacinth, cattle grazing and fishing activities at Basai Wetland; adversely affected the flamingos. At the Najafgarh Jheel, cattle grazing was considered to be the major threat, followed by the overgrown water hyacinth, fishing activities and collision with high tension power lines.

Keywords: Cattle grazing, Gurugram, habitat, population, water hyacinth, wetland.

Flamingos are gregarious birds that live in flocks, ranging from a few to thousands often referred to as Pat (Tere 2005; Johnson & Cezilly 2007). The Greater Flamingos *Phoenicopterus roseus* are the largest, and most common among all the species of flamingos. Food and suitable habitat are key factors affecting its distribution (Ali 1987; Jenkin 1957). The Greater Flamingos primarily feed on phytoplankton, zooplankton, crustaceans, molluscs, sedge seeds and the remains of higher plants (Ali 1987; Tere 2005). Availability of food, water quality, depth, and influence of predator are some important factors that influence the population and distribution of waterbirds (Arengo & Baldassarre 1995; Baldassarre & Arengo 2000; Pirela 2000; Tuite 2000).

Flamingos use habitats including fresh and salt water, brackish water, shallow lagoons, alkaline lakes, saltpans, and mudflats (Ali 1987; Grimmett et al. 1998). Being wetland specialists, Greater Flamingos are found to feed, roost, and nest in the wetlands, hence any change or loss in their habitat is considered a significant threat.

The present study was conducted to assess the population structure and to document conservation threats at Basai wetland and Najafgarh Jheel Bird Sanctuary, which are declared Important Bird Areas

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(IBA) by BirdLife International (Islam & Rahmani 2004). Population abundance and conservation threats for Greater flamingos were carried out in Gurugram District of Haryana. The current study recommends conservation measures to mitigate threats to flamingos and other species of waterbirds in these IBA sites.

Study area

Basai wetland

Basai wetland (28.468N, 76.981E; 216–219 m) is named after the village Basai, in Gurugram District in Haryana, India. The wetland close to Basai-Dhankot railway station and 8 km from the Sultanpur National Park. It is a perennial shallow water wetland with an area of 250 acres and is an IBA that has global conservation significance as it supports populations of several endangered, vulnerable, and threatened bird species (Islam & Rahmani 2004).

Najafgarh Jheel Bird Sanctuary

Najafgarh Jheel Bird Sanctuary (28.498N, 76.946E), located on the Delhi-Haryana border, and estimated around 7 km long, is the part of Sahibi River. The Najafgarh Jheel Bird Sanctuary extends to two villages, Kherki-Majra and Dhankot with an area of 298 acres, in the Gurugram District of Haryana, India. As untreated sewage flows into it, the Jheel is one of the most contaminated, though still an important habitat for many species of birds and plants.

Methods

The selected sites were surveyed on a monthly basis, from May 2019 to February 2020. The data were collected from sunrise to sunset. A combination of field observations, and time series imagery were used to identify changes in the open water area. Observations were carried out by using a Nikon 8 X 40 field binoculars and a Nikon SX60 camera. Birds were counted monthly using the point count method (Sutherland 2006; Bibby et al. 2000) and locations of each sighting of flocks were recorded by means of a hand-held GPS device. To construct a distribution map of the study area the geographic information system (GIS) software (Arc-GIS 10.5) was used. Various threats were determined through direct observations. A total of 17 people were interviewed throughout the study period. To reach study sites at various locations, different modes of transport were used. Adults and immature (sub-adults) birds were identified based on their plumage (Allen 1956; Johnson & Cezilly 2007).

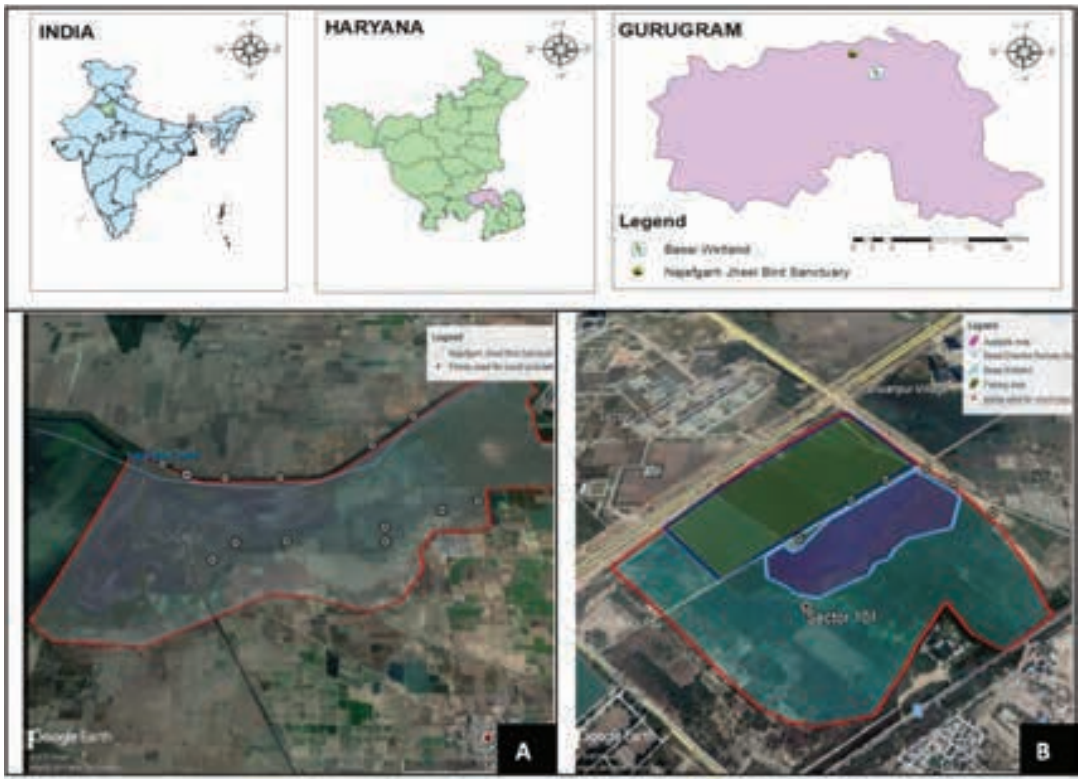

Figure 1. Study area: A—Najafgarh Jheel Bird Sanctuary | B—Basai Wetland (23.v.2020).

Results

Population structure

A total of 65 flocks of flamingos were observed, and 6,768 individuals of Greater Flamingos were counted from May 2019 to February 2020. Najafgarh Jheel Bird Sanctuary holds a major proportion of their population comprising 91.78 % and Basai wetland holds 8.21% of their population (Table 1).

Among 6,768 individuals of Greater Flamingos 52.46 % were classified as adults and 47.53 % were juveniles (sub-adults), while chicks were not observed. The number of adults observed were slightly more as compared to juveniles at both the wetlands (Figure 2).

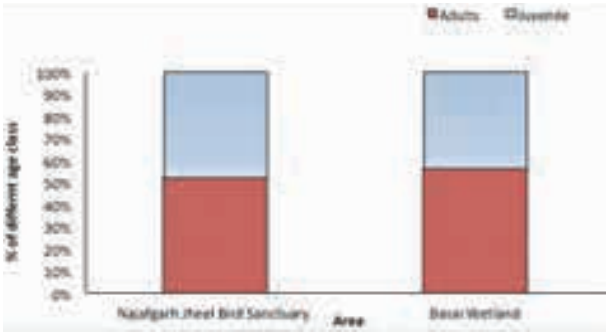

Figure 2. Population age structure of Greater Flamingos observed at study area.

Threats

Major threats in study area including habitat destruction, fragmentation, collision with power line, Invasion of water hyacinth, fishing activities, dumping of solid wastes, release of untreated sewage, diverting of water flow, cattle herds, and feral dogs. Being larger in size, Greater Flamingos are attacked by very few predators though a Black Kite *Milvus migrans* was observed attacking them.

Construction of roads along wetlands and draining of wetland are some main anthropogenic activities at Basai Wetland that result in fragmentation and shrinkage of habitats (Image 1). Overgrowth of water hyacinth, cattle grazing, and fishing activities at Basai Wetland, also adversely affect the flamingo population.

At the Najafgarh Jheel, cattle grazing was observed to be the major threat, followed by the overgrown water hyacinth, fishing activities, and collision with high tension power lines. There is a huge network of powerlines in the area of Najafgarh Jheel Bird sanctuary that pose a high risk to Greater Flamingos (Image 2) and other birds. As this site was not frequently visited by birdwatchers, incidents of bird collisions with powelines remained unnoticed.

Both study sites, wetlands are infested with water hyacinth observed throughout the year and that confines the feeding area (Image 3).

Discussion

Distribution of Greater flamingos is associated with their habitat as these birds are habitat specialists and depend thoroughly on wetlands as they roost, feed, and nest in an aquatic habitat. During the present studies, 91.78 % Flamingo were recorded at Najafgarh Jheel Bird Sanctuary. It is important to monitor flamingo population and how they adapt to current conservation threats, to find out strategies for ensuring their survival. The above-mentioned conservation threats are observed to affect flamingos' distribution and abundance at both the wetlands. Wetlands are constantly facing enormous anthropogenic pressures (Prasad et al. 2002), owing to the rapid urbanization that causes the native species to become eventually extinct in a specific area (Godefroid 2001). Regular decline in level of water at Basai wetland due to various anthropogenic activities (Figure 3), reduces the population of Flamingos. Less number of birds were recorded near human houses or where people move around. It is observed at the nesting colony elsewhere, with a slight disturbance (anthropogenic or natural) flamingos abandon the colony and, consequently, to a failure of nesting (Rameshchandra 2014). Here at both these study locations no breeding and nesting were observed, probably due to human disturbances including fishing and cattle grazing activities.

Flamingo collision with electrical lines is listed as a hazard (Parasharya & Tere 2006; Johnson & Ceilly 2007),

Table 1. Number of Greater Flamingo censuses from May 2019 to February 2020.

Study Area	Number of flock	Flock range	Adult	Juvenile	Total number	Average population
Najafgarh Jheel Bird Sanctuary	45	5 to 214	3238 ± 227	2974 ± 201	6212	621 ± 414
Basai Wetland	20	13 to 49	313 ± 16	243 ± 14	556	55.6 ± 26

*± = standard deviation

Image 1. Construction of roads along Basai wetland resuts in shrinkage of Basai wetland. © Amit Kumar

Image 2. Risk of collision with powerline at Najafgah Jheel Bird Sanctuary. © Amit Kumar

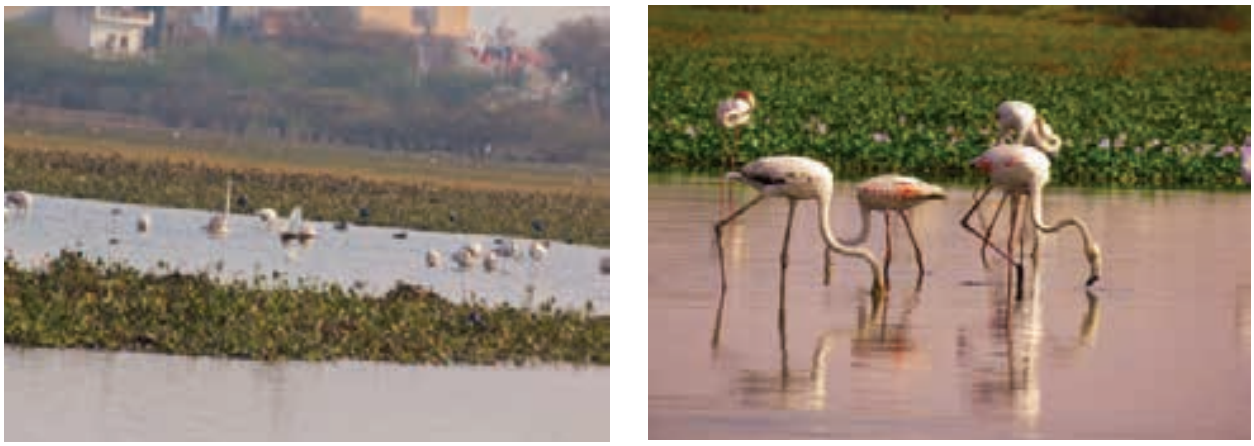

Image 3. Invasion of water hyacinth: A—Basai Wetland | B—Najafgarh Jheel Bird Sanctuary. © Amit Kumar

which affect the population locality (Childress et al. 2008). Our finding shows that collision with powerlines is a threat that was observed at Najafgarh Jheel Bird Sanctuary that was responsible for the mortality of Flamingos and other birds (Figure 5) as observed by other researchers at other Flamingos inhabiting sites (Tere & Parasharya 2011; Rameschandra 2014). Normally, birds collide with powerlines at night and sometimes during the day as well in some instances. Flamingos are reported to fly at night and in low light conditions (Ogilvie & Ogilvie 1986; Johnson & Cezilly 2007). Repeated instances of mortality due to wire collision have been reported at various sites of Gujarat, where a total of 76 flamingo death were recorded by Tere & Parasharya (2011); Rameshchandra (2014) reported that around 50 flamingos were found dead at Kumbharwada site of Gujarat. Mortality of Sarus Crane due to collision with power lines was reported by Sundar & Choudhury (2005); Gosai et al. (2016).

A rapid spread of water hyacinth has been noted by us, at both the habitats (Figure 5). This growth progressively reduces the open water area, available to the flamingos. If this encroachment by hyacinth is not controlled, it will adversely affect the population of flamingos.

Following are some measures to be considered:

1. Water Hyacinth *Eichhornia crassipes* could be utilized for bedding material for mushroom cultivation and as bio fuel (Bote et al. 2020), as an effective means of economic utilization of the weed. This would also raise the state's revenue, in addition to generating employment at local level and value added goods.

2. To reduce the collisions with powerlines at Najafgarh Jheel Bird Sanctuary, the effective measure suggested by Tere & Parasharya (2011) to be adopted.

3. Restriction of fishing during specified times of the year, licensing of capture permit and limits, fencing some of the selected portion, are possible protection measures.

4. Sewage water must be treated before release into these habitats. It will help to improve the water quality and effluents produced from treatment can be reused for agricultural and other purpose. This will also prevent the lake from being contaminated.

5. Our study shows that Najafgarh Jheel holds a large population of Greater Flamingos, so the conversion of Jheel into a protected flamingo park would help protect the population of Greater Flamingos, along with other water birds and associated fauna and flora. This would also help to increase the state's revenue as it will increase tourism.

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OPEN ACCESS

SHORT COMMUNICATION

First report on the occurrence of Sargassum Weed Fish *Histrio histrio* (Lophiliformes: Antennariidae) in Nigeria deep water, Gulf of Guinea

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Abstract: We report the first occurrence of Sargassum Weed Fish *Histrio histrio* at Bonga Field in Nigeria Outer Continental Shelf approximately 120 km south-east of Delta State in February 2014. At high tides and under difficulty, we sampled some seaweeds in the epi-pelagic realm using a secured standard plankton net to the environmental research vessel that was cruising at a dead speed (≤4 knots). Upon examination of the weeds we collected, one adult Sargassum Weed Fish along with two gelatinous fingerlings were realised. This finding suggests the probable occurrence of more population of Sargassum Weed Fish in their macro-habitat (the Sargassum seaweeds) which are abundantly bound in the Gulf of Guinea deep waters. The specimen was photographed on-board and preserved immediately in 10 % formalin solution for a 24-h period and was thereafter reprocessed, and permanently preserved with 70 % ethanol. We recommend a major study of the marine seaweeds and their colonisers amongst Gulf of Guinea member states.

Keywords: Bonga Field, Frogfish, Nigeria Offshore, Pelagic Zone, Seaweed.

Sargassum weeds are bound in abundance in the Gulf of Guinea (GoG) stretch but have not been examined as habitats and niches for several marine organisms, as evident from the lack of publications. These weeds are essential habitats to lots of pelagic dwelling organisms, for example; plankton, parasitic forms, and fishes (Kingsford 1992; Wells & Rooker 2004; Rogers et al. 2010; Rampersad 2016).

The identification and conservation of essential fish habitat was advocated as prerequisite to building healthy and sustainable fisheries (Rosenberg et al. 2000). Till date, considerable works have been focused upon characterising the spatial and temporal patterns of habitat use by fishes (Lindeman et al. 2000; Wells & Rooker 2004), and these efforts have led to valuable information regarding the physical attributes and biological significance of these habitats. Unfortunately, information on habitat use of pelagic species are limited and one of such studies was carried out in the western Atlantic (Wells & Rooker 2004). The pelagic zone is typically characterised by its lack of physical structure and previous studies suggest that many pelagic organisms associate with structures such as the algal mats or seaweeds, particularly during early life stages (Dooley 1972; Rountree 1990; Kingsford 1992; Wells & Rooker 2004).

This paper seeks to document the first occurrence of the Sargassum Weed Fish *Histrio histrio* in Nigeria deep water. We therefore, use this medium to welcome

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Competing interests: The authors declare no competing interests.

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collaborative work on this subject in future.

Materials and Method

The Study Area

The Bonga oil field is located in Oil Mining License (OML) 118 (4°35'47"N, 4°37'27"E), Offshore-Nigeria, with the license area lying about 120 km off the Nigeria coastline (Figure 1). The water depth of the block range from 1,000 m to 1,150 m and the Bonga field is located in approximately 1,030 m of water. The field was discovered in 1995 and began first production in November 2005.

The field is characterised by heavy precipitation and high solar radiation. The North and South Atlantic subtropical highs and equatorial low-pressure system control its climate. Rainy season is between February and November, while dry season is between December and January. During the dry season, there may be haze and thick fog at dawn due to the dust carried by the prevailing Harmattan winds. The dominant waves are large swell waves generated by the prevailing south-south west winds offshore Nigeria. A secondary set of short wavelength waves generated by episodic surges in the southeast winds just off the Namibian coast manifest in the Bonga field area from 214º direction. The two dominant wind systems are the South West Trade Wind (or Tropical Marine Air Mass) and North East Trade Wind (or Tropical Continental Air Mass). The South West Trade Wind originates from the Southern Hemisphere around St. Helens from where it initially moves as the South Easterly Wind and then veers eastwards to become the South Westerly Wind as it crosses the equator (SNEPCo 2014).

Sampling

We sampled for aquatic weed (Sargassum seaweed) in February 2014 while conducting a major environmental study. A 55-micron mesh size plankton net was lowered onto the sea onboard an environmental vessel while cruising at a low speed of 4 knots amidst high tide. The sampler held the net against the direction of the water current (the bow heading) while securing himself with harness by the portside. The collected weeds were introduced into a small bowl and examined. Our interest was to preserve the weeds for a museum, fortunately we harvested an adult Sargassum weed fish which was immediately preserved in 10 % formalin solution for 24

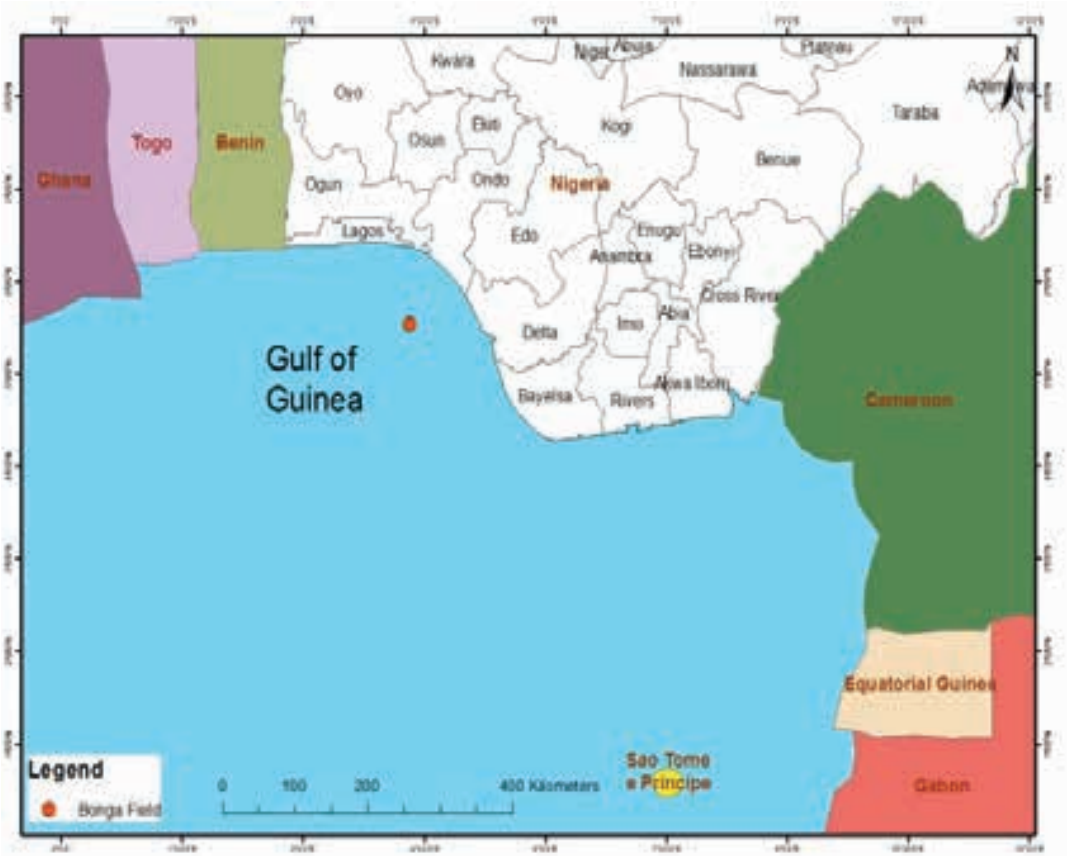

Figure 1. Map of the Bonga Field in the Gulf of Guinea.

h. It was there after removed and washed in sea water, and again introduced into 70 % ethanol for further studies. The specimen was identified online onboard at various websites. Specimen was photographed freshly onboard. We also recorded pH, total dissolved solids, electrical conductivity, turbidity and salinity using HANNA probe and turbidometer for in situ studies. While temperature was measured using mercury in glass thermometer calibrated from 0–100 ^{0}C (Krisson model-59). Every other parameters were measured by dipping the calibrated HANNA probe and turbidometer into the sampled sea water immediately after collection, and the corresponding values read from the digital display on the screens were recorded.

Table 1. Measured values of some abiotic conditions/sea state in Bonga field.

Environmental variables	Value/ state
Water Temperature (^{0}C)	27.9
pH	8.18
Total Dissolved Solids (mgL^{-1})	25060
Dissolved Oxygen (mgL^{-1})	3.29
Electrical Conductivity (µScm^{-1})	50120
Turbidity (NTU)	0.87
Salinity (PSU)	32.74
Swell (m)	Medium (2–4)
Visibility (km)	Good (>5)

Results and Discussion

The environmental variables (Table 1) such as water temperature, pH, total dissolved solids, dissolved oxygen, electrical conductivity, turbidity and salinity had their values within tropical seas condition (EGASPIN 2002).

The classification of the specimen *Histrio histrio* and the common name in parenthesis is given thus (Rampersad 2016):

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterigii (Ray-finned Fish)
Order: Lophiliformes (Anglerfish and Frogfish)
Family: Antennariidae (Frogfish)
Genus: Histrio G. Fischer, 1813

***H. histrio* Linnaeus, 1758 (Sargassum Weed Fish)**

The fish was harvested from Sargassum seaweed *Sargassum fluitans* which also harboured a rich community of plankton. The nature and the occurrence of the Sargassum Weed Fish is in consistency with previous reports (Wells & Rooker 2004; Rogers et al. 2010). The colonization of Sargassum mat by pelagic fishes of which *H. histrio* may not have been an exception was reported by Wells & Rooker (2004) from the Gulf of Mexico and Bray & Thompson (2020) from Australia.

The Sargassum Weed Fish is also known as Frogfish. Amongst its other names across the world are: Marbled Angler, Mouse Fish, Sargassum Anglerfish, Sargassum Frogfish, Sargassumfish, and Sargassum-fish (Bray & Thompson 2020). It is the only pelagic member of the frogfish family Antennariidae, which is considered an obligate associate of floating mats of the brown algae *Sargassum natans* and *S. fluitans* (Adams 1960; Dooley 1972; Pietsch & Grobecker 1987; Wells & Rooker 2004; Rogers et al. 2010). Only one adult form and two gelatinous fingerlings were harvested from the weed colonies. Before now, there was no report on the occurrence of this fish in the Gulf of Guinea.

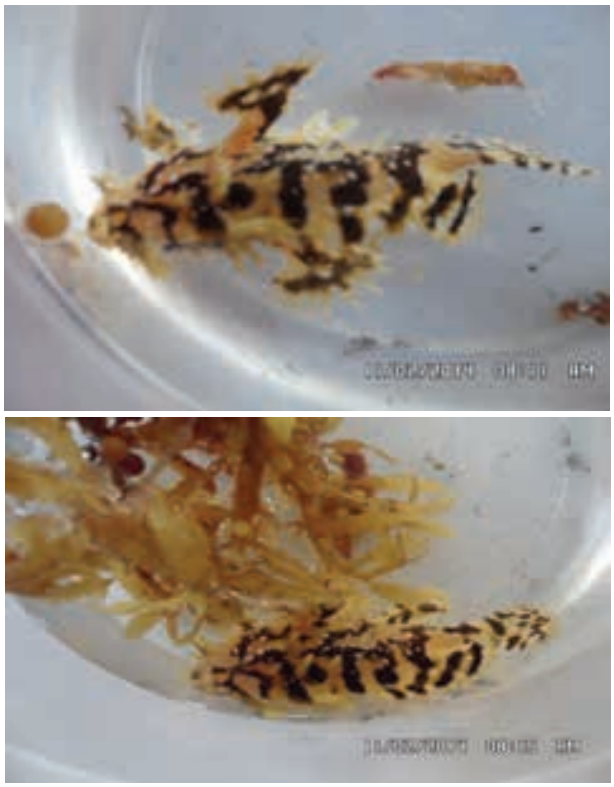

Image 1. Sargassum Seaweed Fish *Histrio histrio* 6.1cm with Sargassum seaweed. © MV African Vision by ARD at Bonga field.

A detailed description of its reproduction, habitats and biology was published earlier (Rogers et al. 2010; McEachran et al. 2015; Rampersad 2016) based on the study from the USA, Trinidad & Tobago, the Pacific, and Nigeria most recently. The specimens (Image 1) are in conformity to the body size, colourations and habitat types by the works of the aforementioned authors.

The standard measurement (i.e., total length, TL) of the adult specimen from Bonga field, offshore Nigeria in the Gulf of Guinea was 61mm (Image 1) but could be up to 100 mm (Rogers et al. 2010). Meanwhile, the gelatinous juvenile forms were 0.8 and 0.9 cm, of which their pictures were not good enough for documentation purpose due to their denaturation upon preservation.

Its distribution cut across both the temperate and tropical regions of the world, such as, the Caribbean Basin, Sargasso Sea, western Pacific, and Indian Oceans (McEachran et al. 2015) and currently in the Gulf of Guinea. Its reproduction involves courtship between the male which closely follows the female, rushing to the epipelagic region to spawn. Spawning is frequent and regular for more than a two week period. They produce eggs on the surface and have an appearance of being blunt at both ends with a slightly larger middle. After the female releases her eggs the male externally fertilises them as it is in other fishes. The Juveniles then move to depths exceeding 200m, where they feed and become adults, and thereafter return to the Sargassum weeds above. The juveniles feed on other fish eggs and small crustaceans, amphipods, decapods, euphausids and shrimps, whereas adults feed on other fish and shrimps among the seaweed at the surface (Rampersad 2016). On its biology, Rampersad (2016) reported again that the sargassum fish can hold the ciguatoxin poison, accumulated from its food, and can cause ciguatera poisoning in humans. This could be one of the reasons while the species is of Least Concern on the IUCN Red List (McEachran et al. 2015) and importantly, its population thrives since it is not consumable by humans. The habitat and ecology correspond to what we observed and documented at Bonga field in the Gulf of Guinea. Whereby they usually find refuge in the floating Sargassum seaweed mats which can cover a depth of 0–5 m. In these Sargassum mats, adults and eggs can be found but, the larvae of the species usually develop in water columns between 50–600 m (McEachran et. al. 2015; Rampersad 2016).

In conclusion, we strongly believe that there could be more to learn from *Histrio histrio* if given the opportunity to carry out a major study regarding species diversity, community structure, its seasonal preference and occurrences in the Gulf of Guinea member states. Since, the species is not documented in FAO book of fishes of economic importance and it is of Least Concern on the IUCN Red List, it is therefore crucial to understand its biology and tropical ecology as well as population in addition to existing documentations. This will further tell whether it is threatened in this region owing to increasing deep sea anthropogenic activities or not.

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SHORT COMMUNICATION

A new distribution record of stomatopods *Odontodactylus japonicus* (De Haan, 1844) and *Lysiosquilla tredecimdentata* (Holthuis, 1941) from the Puducherry coastal waters, east coast of India

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Abstract: Stomatopods in India are well known with 79 species recorded to date. Here I report the *Odontodactylus japonicus* (De Haan, 1844) and Golden Mantis Shrimp *Lysiosquilla tredecimdentata* Holothuis, 1941 for the first time in Puducherry coastal waters. A single specimen of *Lysiosquilla tredecimdentata* was collected from by-catch in the Nallavadu landing centre, Puducherry coast on 19 November 2019 and two specimens of *L. tredecimdentata* were recorded again in Pillaichavadi landing centre of Puducherry coast on 22 November 2019. One specimen of *Odontodactylus japonicus* was collected at Nallavadu landing centre, Puducherry coast on 20 December 2019. The present study was undertaken to identify the status of distribution, habitat, and ecological aspects along with the information of spread, confinement, endemism as well as rare, threatened and endangered species. The significance of these new observations is to discern the taxonomic position and characteristics for better understanding of the mantis shrimp group. The specimens were identified, described, illustrated, and measured morphometrically.

Keywords: By-catch, Golden Mantis Shrimp, morphometric measurements.

Macro invertebrates, especially crustaceans, molluscs, and echinoderms play an important role in ecological interdependence with other species and have a marked influence on benthic community structure (Venkataraman & Wafar 2005; Bijukumar 2008; Wafar et al. 2011). Stomatopods, also called mantis shrimps, are elongate, flattened, shrimp- or lobster-like crustaceans (Carpenter & Neim 1998) and notable for their aggressive behaviour. Stomatopod crustaceans are common members of benthic ecosystems in tropical and subtropical marine and brackish waters throughout the world (Antony et al 2010). The attributed feature of stomatopods are the large well-built raptorial appendages for capturing the prey by 'spiking' or 'smashing' depending on the dactyl is extended or held folded while going on a foray. Stomatopods are prevalent and appealing inhabitants of coral reefs. They form a cardinal status in the ocean food chain (Caldwell 2006). They are a source of food and medicine (Subasinghe 1999). To date, about 485 species, 115 genera, and 17 families of mantis shrimp are described (WoRMS 25 December 2018). The diversification of stomatopods in India put the foundation for the publication of the first monograph of the Indo-Pacific mantis shrimps (Stomatopoda) (Kemp 1913). Succeedingly, numerous studies drawn out the

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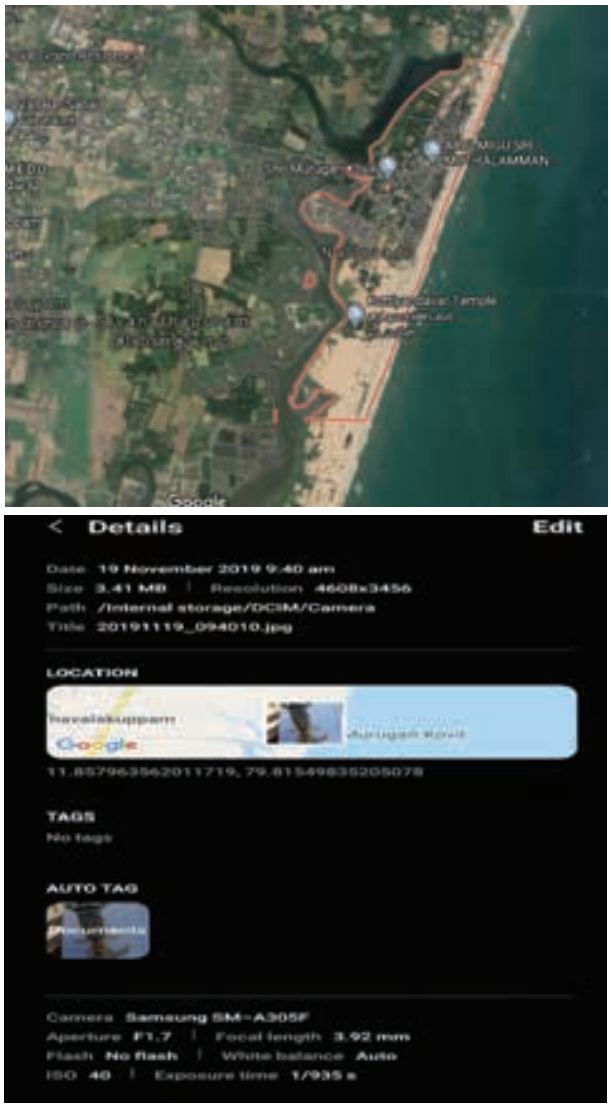

Image 1. Map showing the place of Nallavadu Landing, Puducherry.

information of Indian Stomatopoda (Kemp & Chopra 1921; Shanbogue 1969, 1986; Ghosh 1991, 1995, 1998); the most recent checklist of Indian stomatopods records 79 species (Roy & Gokul 2012). Although stomatopods occur along the entire Indian coast, most published records are from localities on the eastern coast. Recent studies of commercial trawl by-catch primarily along the southern and southwestern coasts (Tamil Nadu and Kerala) resulted in numerous new records and discoveries of decapod crustaceans (Komai et al. 2013; Kumar et al. 2013; Ng et al. 2016, 2017; Yang et al. 2017). The pan tropical stomatopod genus Lysiosquilla, which includes the largest known stomatopods, comprises 12 species, five of which are reported in the Indo-West Pacific region. The odontodactylid mantis shrimp is the only genus found in the family Odontodactylidae. These are relatively small when compared to banded mantis shrimp and it displays rare occurrence in Indian waters. The present study documented the first record of *Odontodactylus japonicus* and Golden Mantis Shrimp *Lysiosquilla tredecimdentata* from Puducherry coastal waters, eastern coast of India.

Materials and Methods

A single specimen of *L. tredecimdentata* was collected from by-catch in the Nallavadu landing centre, Puducherry coast on 19 November 2019 (Image 1) and two specimens of *L. tredecimdentata* were recorded again in Pillaichavadi landing centre of Puducherry coast on 22 November 2019 (Image 3). One specimen of *O. japonicus* was collected at Nallavadu landing centre, Puducherry coast on 20 December 2019 (Image 2). All the specimens were collected as a bycatch by hand picking and its identification was carried out using standard guidelines (Manning, 1978; Ahyong et al., 2008). Terminology, description and morphometric measurements generally follow Manning (1978) and Ahyong (2001).

Results

***Odontodactylus japonicus*, De Haan, 1844**

Class: Malacostraca Latreille, 1802
Order: Stomatopoda Latreille, 1817
Family: Odontodactylidae Manning, 1980
Genus: Odontodactylus Bigelow, 1893
Species: *japonicus* De Haan, 1844

Material observed: Paratype, ZSI/MBRC-D1-623, Male, 20.xii.2019, Nallavadu, Puducherry, 11.858N, 79.815E, NW-3543 (Image 2, Table 1), at 18 km, 30 m depth, coll. Nithya Mary

Systematic position

Diagnostic characters

Carapace, thorax, and abdomen smooth, not trimmed with any longitudinal ridges. Antennular scale with smooth anterior margin, without setae in adults. Rostral plate triangular. Raptorial claw short and strengthened at base of terminal segment, adapted for smashing prey; inner margin of dactyl not toothed with more than 5; proximal margin strongly inflated; telson mid-dorsal surface with distinct median carina and four longitudinal carinae either side of midline. Uropodal exopod proximal distinctly longer than distal segment; outer margin with 10–12 movable spines.

Colour in life

Overall pink in colour. Antennal scale white dorsally

Table 1. Morphometric measurements of *Odontodactylus japonicus*

Measurements (mm)	*O. japonicus*
Total length	126
Carapace length	32
Carapace width	39
Thorax length	15
Abdomen length	58
Rostral plate length	4
Rostral plate width	7
Antennal scale length	5
Antennal scale width	3
Raptorial propodus length	29
Raptorial propodus depth	10
Telson length	21
Telson width	35
Total wet weight	25g

Image 2. *Odontodactylus japonicus*.

with purple and orange ventrally. Uropod yellow with red setae. Exopod with outer movable spines yellow orange with blue posterior margin; distal end of endopod and exopod with red setae. Anterior carapace with brown patches.

Remarks

Specimen of *O. japonicus* examined above show adult diagnostic characters. The longitudinal carina on the inner intermediate denticle and the colour pattern resembles adults. It inhabits in level sandy or shelly substrates from 30–80 m depth. *Odontodactylus* is the only genus found in the family Odontodactylidae. Nothing much is known about the biology of odontodactylids and there is no organised fisheries known to exist for them. Ahyong & Kumar (2018), reported the first record of *O. japonicus* from Muttom, Tamil Nadu. Since then, Kumar reported *O. japonicus* in east coast, after which there is no record of *O. japonicus*. We report this species for the first time in Puducherry coastal waters, the east coast of India. The previously known Indian Ocean distribution of *O. japonicus* is highly disjunct and hence the present record has enlarged the distributional gap.

Ecology and Distribution

Homed in simple U-shaped burrows and lined and covered with rubble (Caldwell 2006). Indo-West Pacific, from the western Indian Ocean to Australia and Japan (Manning 1967).

***Lysiosquilla tredecimdentata* Holthuis, 1941**

Class: Malacostraca Latreille, 1802
Order: Stomatopoda Latreille, 1817
Family: Lysiosquillidae Giesbrecht, 1910
Genus: *Lysiosquilla* Dana, 1852
Species: *tredecimdentata* Holthuis, 1941

Material observed: Paratype, ZSI/MBRC-D1624, Male, 19.xi.2019, Nallavadu, Puducherry, 11.858N, 79.815E, NW-3543 and again 22.xi.2019, Pillaichavadi Puducherry, 12.008N, 79.858E, NW 4892 (Image 1, 3, Table 2), at 18 km, 30 m depth, coll. Nithya Mary.

Diagnostic characters

The texture of Carapace, thorax, and abdomen are smooth without any carina or ridges; raptorial claw large and slender with 9–13 teeth. Rostral plate cordate and broad. Eyes T-Shaped, with large, bilobed cornea; pereiopods 1–3 with slender, elongate endopod. Uropodal protopod with small spine anterior to endopod articulation. Telson lacking movable sub median teeth and longitudinal carina.

Colour in life

Lysiosquillids are clearly banded with alternate light and darkly pigmented bands. Carapace with three dark, broad, transverse bands intervened by narrower pale bands. Uropodal exopod with distal ½ of proximal segment and proximal 2/3 of distal segment black; outer movable spines dark red. Uropodal endopod with distal 2/3 black. Antennal scale with dark brown outline. Pereiopods with pink setae on distal segment.

Remarks

Morphological characteristics of the specimen

Table 2. Morphometric measurements of *Lysiosquilla tredecimdentata*

Measurements (mm)	*L. tredecimdentata*
Total length	295
Carapace length	65
Carapace width	85
Thorax length	69
Abdomen length	146
Rostral plate length	8
Rostral plate width	13
Antennal scale length	26
Antennal scale width	5
Raptorial propodus length	13
Raptorial propodus depth	45
Telson length	45
Telson width	69
Total wet weight	250 g

Image 3. *Lysiosquilla tredecimdentata*.

indicate that it belongs to banded mantis shrimps from the family Lysiosquillidae (Giesbrecht, 1910) and it is perfectly synchronized with the original description given by Holothuis (1941) and Shanbhogue (1970). Lysiosquillids live in monogamous pairs in long, deep burrows in coral reef flats, mud flats and soft sub tidal substrates (Ahyong et al. 2008). Pillai & Thirumilu (2006) have reported *L. tredecimdentata* from Cuddalore fishing harbour, Tamil Nadu coast of India. Silambarasan & Senthilkumaar (2014) reported the first occurrence of *L. tredecimdentata*, from Kasimedu fishing harbour, Chennai coast, Tamil Nadu, India and Chesalin (2013) also reports first record of the same species in the Omani waters of the Arabian Sea.

Ecology and Distribution

The species inhabits deep burrows on intertidal sand and mudflats, and level sub tidal substrates to 30 m (Ahyong 2001). Almost nothing is known about the biology of Lysiosquillids. According to Manning (1998) they make burrows with double entrance, one at each end, in level-bottom habitats in shallow water, from shore to a depth of about 25 m. Although they generally hunt from the mouth of their burrow, they occasionally leave their burrows and may be caught at night by lights or in trawls.

The known distribution of *L. tredecimdentata* is from Yemen (Red Sea) (Holthuis 1941) southward to Madagascar (Manning 1968) and South Africa (Manning 1978); from India eastward to Thailand, Vietnam, Taiwan, Australia and the central Pacific (Ahyong 2001). This is the first record of this species from the Puducherry coastal waters.

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New records of *Agriocnemis keralensis* Peters, 1981 and *Gynacantha khasiaca* MacLachlan, 1896 (Insecta: Odonata) from Maharashtra, India

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Abstract: *Agriocnemis keralensis* Peters, 1981 is reported for the first time from Maharashtra, India. Previously it was known from Kerala and Goa states. In this paper we report *A. keralensis* from Thakurwadi and Bambuli wetlands and Chipi Plateau, Sindhudurg District. Also, the new record of *Gynacantha khasiaca* MacLachlan, 1896 is confirmed on the basis of specimens collected from Sindhudurg District. Hence, we report the range extension of both *A. keralensis* and *G. khasiaca* in northern Western Ghats. Apart from this, a combined checklist of Odonata fauna of Thakurwadi (51 species), Bambuli wetlands (44 species), and Chipi Plateau (51 species) is provided.

Keywords: *Agriocnemis*, Anisoptera, *Gynacantha,* range extension, Sindhudurg, Western Ghats, Zygoptera.

Marathi abstract: *Agriocnemis keralensis* Peters, 1981 ही टाचणी सिंधुदुर्ग जिल्हा, महाराष्ट्र राज्यात पहिल्यांदाच मिळाली आहे. याआधी ही टाचणी केरळ आणि गोवा राज्यातून ज्ञात होती. या पेपरमध्ये आम्ही *A. keralensis* च्या नोंदी ठाकूरवाडी आणि बांबुळी पाणथळ जागा आणि चिपी पठार येथून करीत आहोत. तसेच, सिंधुदुर्ग जिल्ह्यातून गोळा केलेल्या नमुन्यांच्या आधारे *Gynacantha khasiaca* MacLachlan, 1896 या चतुराच्या नोंदीची खातरजमा केली आहे. यावरून *A. keralensis* आणि *G. khasiaca* ची उत्तर पश्चिम घाटातील विस्तारित नोंद आम्ही करीत आहोत. याव्यतिरिक्त ठाकूरवाडी आणि बांबुळी पाणथळ जागा आणि चिपी पठार येथील चतुर आणि टाचण्यांची एकत्रित यादी देण्यात आली आहे.

India is one of the mega diverse countries of the world in terms of biodiversity. Maharashtra, one of the biggest states in India, has 134 species of Odonata (Tiple & Koparde 2015). Western Ghats as a whole harbours 174 Odonata species including 56 endemics (Subramanian & Sivaramakrishnan 2002; Subramanian et al. 2011), which increases the importance of habitat conservation.

The narrow strip of land present between Arabian Sea and Western Ghats is known as the Konkan-Malabar region (Watve 2013). Sindhudurg District is one of the biodiverse places situated in this region (Image 8c). Recently, two new species of Odonata, namely, *Ceriagrion chromothorax*, Joshi & Sawant, 2019 and *Bradinopyga konkanensis*, Joshi & Sawant, 2020 have been described from Sindhudurg. The district is situated in southern Konkan region covers a total of 5,207km^2 of area and is bounded by the Arabian Sea on the west and the Western Ghats on the east. From the mountain streams of the Western Ghats, from perennial rivers to shallow wetlands on lateritic plateaus and large lakes in the district are ideal habitats for odonate species.

In this paper, we report the first record of *Agriocnemis keralensis* from Maharashtra, based on one male and one female specimen each, which is the northernmost record for the species and multiple field observations

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from nearby areas. Also, the presence of *Gynacantha khasiaca* in the Western Ghats is confirmed based on one male and one female specimen, which is the southernmost record for the species. These records are the range extensions for both the species. In addition to this, we provide a combined checklist of Thakurwadi and Bambuli wetlands and Chipi Plateau.

The present work was started in the year 2020 and carried out at three localities consisting of two wetlands and one plateau (see Table 1). AD & YK first observed *Agriocnemis keralensis* at Thakurwadi on 20 July 2020 and subsequently from Bambuli wetlands and Chipi Plateau. AD first observed *Gynacantha khasiaca* from Majgaon on 30 August 2020; 2 males and 1 female of *A. keralensis* were collected from Thakurwadi wetland and 1 male and 1 female of *G. khasiaca* were collected from Majgaon, Sawantwadi Taluka with the help of insect collecting nets. Based on these specimens we report new records of the above mentioned species. All specimens were preserved in 70% alcohol and three of them were deposited at Research Collections, National Centre for Biological Sciences (NCBS), Bengaluru, India and one specimen was deposited at Zoological Survey of India (ZSI), Western Regional Centre, Pune. Collected specimens were examined and photographed under the Lawrence and Mayo microscope, model LM-52-3621 at Shivaji University, Kolhapur. Field photographs of specimens were taken by Canon 760D with a 100mm macro lens and Nikon 7500D with Tamron 90mm lens. Identification of the species was done with the help of standard field guides and Fauna of British India (Fraser 1936). Random survey method was applied to document odonate diversity in all above habitats. Morphological terms refer to Garrison et al. (2006). All measurements are given in mm. Abbreviations in the text: FW= fore wing, HW= hind wing, Ax and Px= antenodal and postnodal nervures, Pt= pterostigma, S1–S10= abdominal segments 1–10. Maps used in Image 8 were created using QGIS v3.14.

Table 1. Localities where survey has been conducted in Sindhudurg District, Maharashtra, India.

	Locality	District	GPS coordinates (N, E)	Altitude (m)
01	Thakurwadi wetland, Kudal Taluka	Sindhudurg	16.01, 73.648	20
02	Bambuli wetland, Kudal Taluka	Sindhudurg	16.043, 73.683	16
03	Chipi Plateau, Vengurla Taluka	Sindhudurg	15.993, 73.522	32
04	Majgaon, Sawantwadi Taluka	Sindhudurg	15.886, 73.820	109

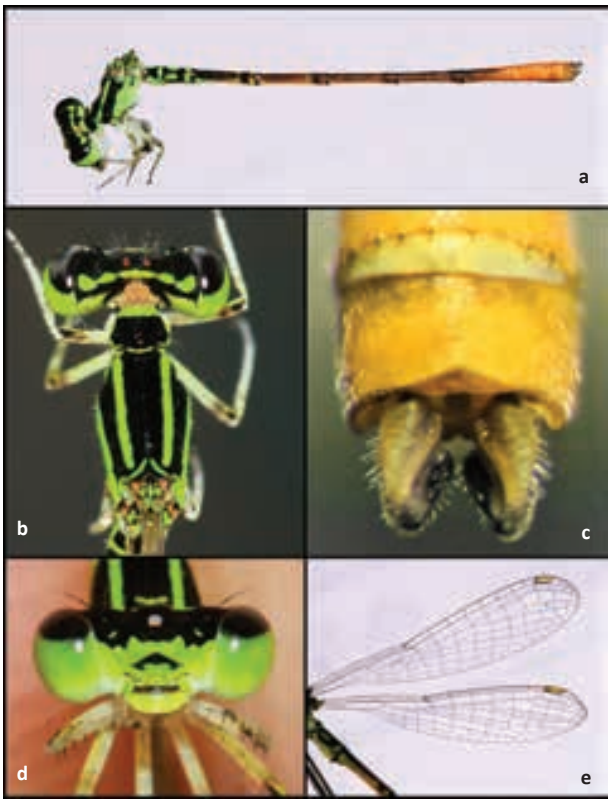

Image 1. *Agriocnemis keralensis* (Peters, 1981) male: a—habitus, lateral view | b—head and thorax, dorsal view | c—caudal appendages, dorsal view | d—face | e—left FW and HW. © a–e—Yogesh Koli.

***Agriocnemis keralensis* Peters, 1981 (Image 1, 2)**

Material examined: Male (NCBS-IBC-BO400): Thakurwadi wetland, Kudal Taluka, Sindhudurg District, Maharashtra, India (16.011^{0}N, 73.648^{0}E, 20m), 20.vii.2020, Yogesh Koli leg.

Female (ZSI, WRC, Ent.4/2828): Thakurwadi wetland, Kudal Taluka, Sindhudurg District, Maharashtra, India (16.011^{0}N, 73.648^{0}E, 20m), 20.vii.2020, Yogesh Koli leg.

Brief description of male (Image 1)

Head (Image 1b, d): Labium, labrum, anteclypeus, postclypeus and base of mandible pale yellowish green; vertex and occiput brownish-black, posterior side of head with two yellowish-green post-ocular spots on either side; eyes black above, greenish below.

Thorax: Prothorax (Image 1b) black with horizontal green stripe on its anterior lobe; posterior margin of posterior lobe bordered with green. Synthorax (Image 1a,b) black on its dorsal side with green antehumeral stripe on each side of mid dorsal carina; metepisternum

Image 2. Field images of *Agriocnemis keralensis* (Peters, 1981): a—male | c—female | d—heteromorph female | *A. pygmaea* (Rambur 1842): b—male. © a—d—Yogesh Koli.

and metepimeron greenish-yellow; broad black stripe on postero-lateral suture. Legs: pale creamy white with black spines; black stripe on extensor surface of femora.

Wings (Image 1e): Hyaline, Ax: FW left and right= 2; HW left and right= 2. Px: FW left= 7, right= 6; HW left and right= 5. Pt twice as long as broad, yellow-ochraceous.

Abdomen (Image 1a): S1 having lateral side greenish yellow and tergum black on dorsum. S2 with black cobra's hood shaped mark on dorsum. S2–6 blackish-brown to brownish-orange on dorsum and pale brown on lateral. Narrow brown ochraceous annules on the posterior end of each segment, more prominent on dorsum; last 3 segments ochraceous orange.

Caudal appendages (Image 1c): Orange to pale brown; cerci conical and slightly curved inwards, longer than S10 and tip black; paraproacts pale brown, shorter than cerci. Measurements: Abdomen including caudal appendages= 15, FW= 8, HW= 9.

Brief description of female (Image 2c, d)

Adult female (Image. 2c): Head, prothorax, and pterothorax similar in colour pattern with male. Wings: hyaline, Pt dirty ochraceous yellow. Abdomen: S1–7 broad black stripe on dorsum which expands laterally at the posterior end, greenish-yellow from lateral and ventral side. S8–10 are black on dorsum, pale green ventro-laterally, oval green patch on antero-lateral of S8; caudal appendages pointed, pale green.

Form Heteromorph (Image 2d): Ground colour orange to pale brown. Head: Labium, labrum, anteclypeus, postclypeus pale yellowish-brown; vertex and occiput black; eyes brown above, pale yellowish-green below. Prothorax: Pale brownish-orange. Pterothorax: Two brownish-orange stripes at mid-dorsal carina and run parallel to each other, orange to pale brown on lateral side with pinkish hue in life. Wings: Hyaline, Pt dirty ochraceous yellow. Abdomen: S1–10 orange to pale brown on dorsal, mid dorsal and lateral side with apical narrow pale yellow annule. S8–10 faint black on dorsum fading towards the base. Caudal appendages: pointed, dirty yellow.

Diagnosis: *Agriocnemis* Seyls, 1869 genus has 11 species in India (Subramanian & Babu 2017). From those species, *Agriocnemis clauseni* (Fraser, 1933), *A. femina* (Brauer, 1868), *A. lacteola* (Selys, 1877), *A. kalinga* (Nair & Subramanian, 2014), *A. dabreui* (Fraser,

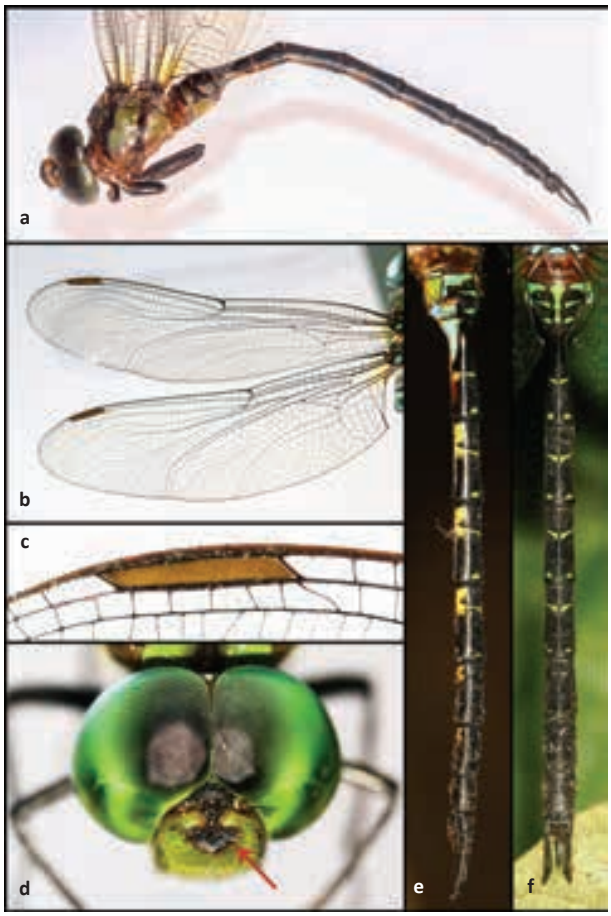

Image 3. *Gynacantha khasiaca* (MacLachlan, 1896) male: a—habitus, lateral view | b— right FW and HW | c—pterostigma, right FW | d—head, dorsal view (Red arrow showing 'T' mark | e—abdomen, lateral view | f—abdomen, dorsal view. © a–f—Yogesh Koli.

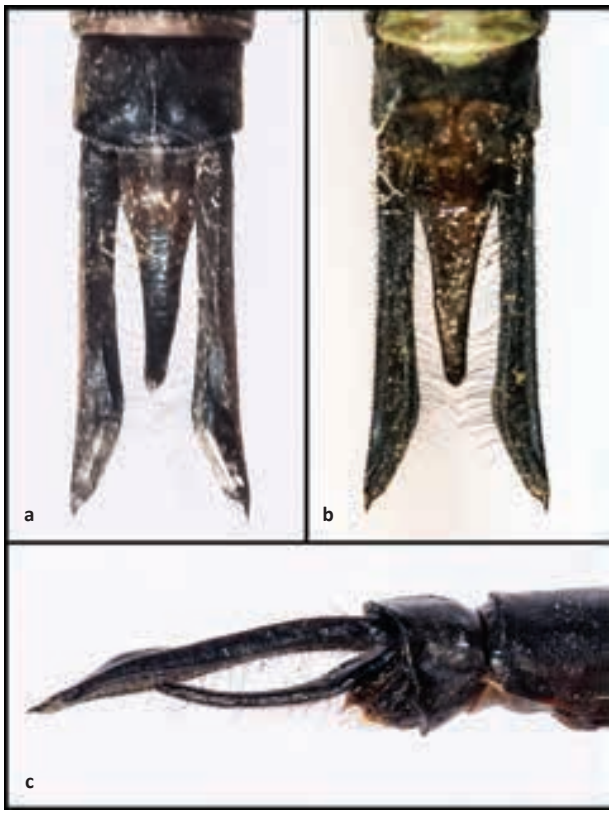

Image 4. Caudal appendages of *Gynacantha khasiaca* (MacLachlan, 1896) male: a—dorsal view | b—ventral view | c—left lateral view. © a–c—Yogesh Koli.

1919) are reported from northeastern India (Nair & Subramanian 2014). In fact, *A. femina* is also reported from the Western Ghats region (Subramanian et al. 2018). *A. pygmaea* (Rambur, 1842) and *A. pieris* (Laidlaw, 1919), *A. splendidissima* (Laidlaw, 1919) are distributed throughout the Indian subcontinent (Kalkman, 2020) . *A. keralensis* is endemic to the Western Ghats (Kalkman 2020). *A. keralensis* is identified by its small size, five post-ocular spots (one horizontal and two spots on either side), blackish-brown to brownish-orange abdomen with 'cobra hood' mark on S2. This species is very similar to *A. kalinga* (Subramanian & Nair, 2014) with respect to cobra shaped hood mark on S2, but differs significantly in case of abdominal colouration. *A. pygmaea* (Image 2b) which occurs with the same locality can be distinguished by the colour of the abdomen and absence of 'cobra hood' mark on S2.

Distribution (Image 8a,c): *Agriocnemis keralensis* was described by Peters in 1981 from Kerala and redescribed by Nair & Subramanian (2014). Recently, it was reported from Goa State (Rangnekar et al. 2010). In this paper, we report the northernmost record of *A. keralensis* from Thakurwadi, Bambuli, and Chipi, which is range extension for the species (Image 8c). A population of *A. keralensis* with good number of males and two females with one heteromorph were observed at Thakrwadi wetland. A total of four individuals were observed at Bambuli wetland. Chipi Plateau had scattered colonies in seasonal ponds with both males and females. No females were observed at Bambuli.

Habitat (Image 7a,b,c): Thakurwadi wetland is a perennial waterbody where many males and two females including heteromorph female of *Agriocnemis keralensis* were found. Individuals were observed in the aquatic grasses. Other species observed were *Agriocnemis pygmaea*, *Urothemis signata*, and *Ceriagrion* spp. Bambuli wetland, a perennial waterbody where four males of *A. keralensis* were found in aquatic grasses. Scattered population was found on lateritic plateau of Chipi in seasonal ponds.

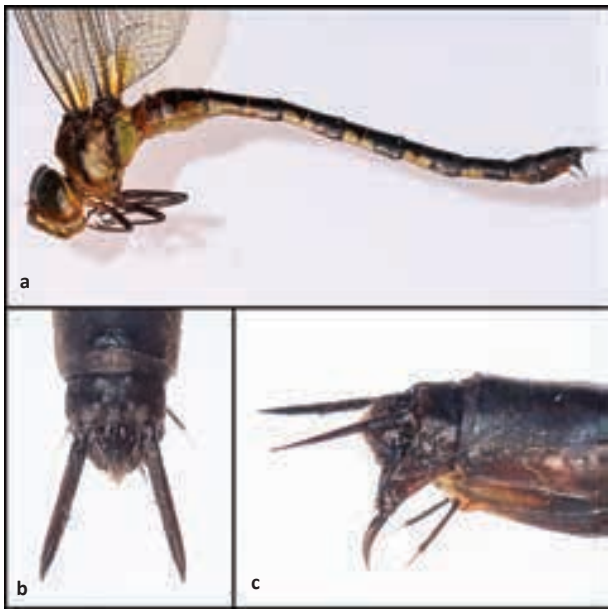

Image 5. *Gynacantha khasiaca* (MacLachlan, 1896) female: a—habitus, lateral view | b—caudal appendages, dorsal view | c—caudal appendages, left lateral view. © a–c—Yogesh Koli.

***Gynacantha khasiaca* MacLachlan, 1896 (Image 3–6)**

Material examined: Male (NCBS-IBC-BO398): Majgaon, Sawantwadi Taluka, Sindhudurg District, Maharashtra, India (15.886^{0}N, 73.820^{0}E, 109m), 30.viii.2020, Akshay Dalvi leg.

Female (NCBS-IBC-BO399): Majgaon, Sawantwadi Taluka, Sindhudurg District, Maharashtra, India (15.886^{0}N, 73.820^{0}E, 109m), 10.ix.2020, Akshay Dalvi leg.

Brief description of male (Image 3,4)

Head (Image 3a,d): Labium, labrum bright olivaceous with ochre hue, antefrons and postfrons olivaceous, postfrons having black coloured 'T' mark with stem towards eyes. Eyes bluish-green above and olivaceous below in life, become dull olivaceous post-mortem. Vertex dull black, occiput dark olivaceous, antennae brownish-black.

Thorax. Prothorax yellow to olivaceous. Synthorax (Image 3a) olivaceous green on dorsum with mid dorsal carina brownish-black. Bright grass green on lateral with sharply defined dark brown stripes on humeral suture

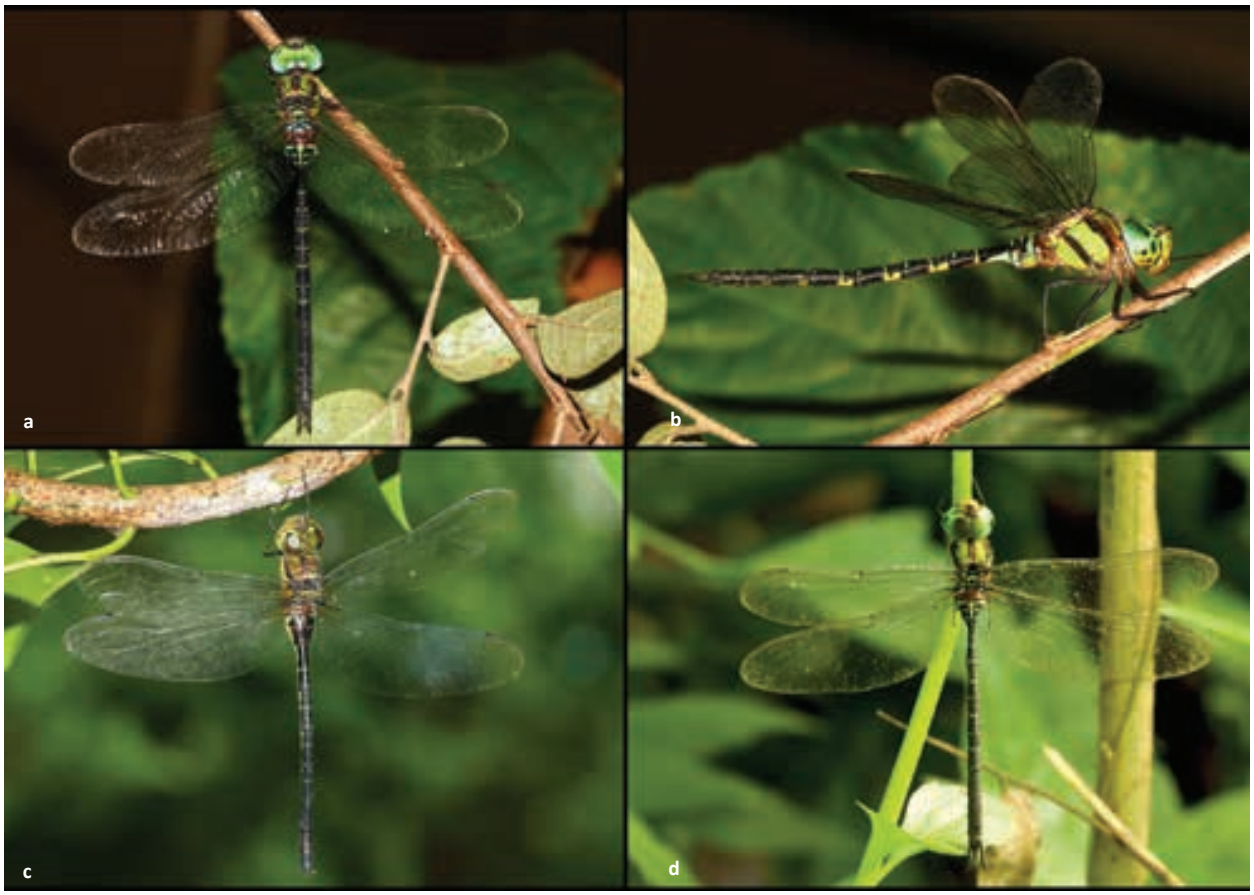

Image 6. Field images of *Gynacantha khasiaca* (MacLachlan, 1896): a, b, d—male | c—female. © a, b, c—Yogesh Koli, © d—Dr Muralidhar G.

Image 7. Habitat photos of: a—Thakurwadi wetland | b—Bambuli wetland | c—Chipi Plateau | d—Majgaon, Sawantwadi. © a—Dattaprasad Sawant, © b–c—Yogesh Koli, © d—Akshay Dalvi.

and postero-lateral suture. A large turquoise blue spot on posterior end of metepimeron separated by a thin brown line from the rest. Ventral part pale brown. Legs: proximally brown, distally dark brownish-black, coxae pale brown

Wings (Image 3b,c): Hyaline, bases of both wings amber coloured, Ax: FW left= 25, right= 23; HW lef= 17, right = 16. Px: FW left= 19, right= 20; HW left= 20, right= 21. FW triangle 5-celled, HW 4–5 celled. Anal triangle 3-celled, anal loop 11–13- celled. Pt dark ochraceous covering five cells in all wings.

Abdomen (Image 3e,f): Tumid at base, significantly constricted at S3, again narrow and cylindrical till the end. S1 brown on dorsum, grass green area on both lateral sides bearing a small yellow spot. S2 black, marked with grass green as follows: narrow irregularly bordered vertical band on dorsum, narrow ring which is incomplete on dorsum, two pairs of lunule shaped spots on each side of mid-dorsal line, ventrally yellow above and pale blue below, auricles pale brown, pale blue above auricles and grass green below auricles. S3–7 black on dorsum and marked with grass green as follows: jugal paired spots and paired apical annules, S3 blue on ventral, S4–7 yellow on antero-lateral. S8–10 black except S8 antero-lateral part having faint yellow markings.

Caudal Appendages (Image 4): Cerci black, almost three times longer than S10 with fine hairs on medial side, apices pointed. Paraprocts black, conical in shape, almost two-thirds the length of cerci, apex blunt.

Measurements: Abdomen including Caudal appendages= 53, FW= 42, HW= 41–42.

Brief description of female (Image 5)

Head, prothorax, pterothorax (Image 5a) similar to the male. Two sharply defined brown stripes on each side of pterothorax. Legs. Brown proximally, brownish-black distally. Wings. Similar to male with amber colour at base. Ax: FW left= 24, right= 22; HW left= 17, right= 16. Px: FW left= 19, right= 18; HW left= 19, right= 20. Abdomen (Image 5a). Tumid at base, less constricted at S3 than male, remaining narrow and cylindrical. S1 pale brown, S2 black and less marked with grass green on dorsum than male, ventro-laterally pale green changing to yellow on ventral. S3–10 similar to male. Caudal Appendages (Image 5b,c). Black, cerci pointed almost as

long as S9, ovipositor dark brown.

Measurements: Abdomen including caudal appendages= 55, FW= 44, HW= 45.

Diagnosis: *Gynacantha* Rambur, 1842 is a genus of large sized dragonflies with 99 species distributed throughout the world (Paulson & Schorr 2020). Among them 14 species are reported in India (Kalkman et al. 2020). *G. khasiaca* was previously recorded from Assam (Laidlaw 1923; Fraser 1936), Meghalaya (Fraser 1922; Kimmins, 1969; MacLachlan 1896) and West Bengal (Mitra 2002). In this paper, we report new locality of *G. khasiaca* in northern Western Ghats which is an extension in range for the species. Here we report first confirmatory record in Maharashtra State and entire Western Ghats. 'T' shape mark on postfrons, sharply defined brown stripes on each side of pterothorax, long and pointed cerci, paraprocts almost two-thirds length of cerci are helpful to distinguish it from other species of *Gynacantha* genus. *Gynacantha cattienensis* Kompier & Holden, 2017 is similar to *G. khasiaca*, but previous species is present in Vietnam and can be distinguished from later by the absence of thoracic stripes, different shape of auricle and cerci.

Distribution (Image 8b,c): *Gynacantha khasiaca* is previously known from India, Bangladesh, Bhutan, and Nepal. In India, it was recorded from northeastern states, i.e., Arunachal Pradesh, Assam, Meghalaya, West Bengal, and coastal areas of West Bengal. In October 2019, *Gynacantha* cf. *khasiaca* was reported from Thakurwadi wetland, Sindhudurg District, Maharashtra on the basis of photograph of a male (Mujumdar et al. 2020) (Image 6d). With this record, now *G. khasiaca* is reported from two localities from northern Western Ghats. This record is the southernmost range of the species in India.

Habitat (Image 7d): Two males and one female of *Gynacantha khasiaca* were observed at Majgaon Village, Sindhudurg District. All the individuals were attracted to light and came in house of AD in the night time. The place has human population surrounded by trees and seasonal natural streams at close proximity.

Result and Discussion

After multiple surveys in Thakurwadi and Bambuli wetlands and Chipi Plateau, we recorded a total of 65 species of odonates, consisting of five families of Zygoptera and four families of Anisoptera (Table 2). Family Coenagrionidae in Zygoptera and family Libellulidae in Anisoptera had the maximum number of species at all three locations (Table 2; Figure 1). Thakurwadi wetland was recorded with the maximum number of species (57 species) with a special mention of *Ceriagrion chromothorax*, *Pseudagrion malabaricum*, and *Indothemis limbata*, apart from *Agriocnemis keralensis* and *Gynacantha khasiaca* (Image 9). Chipi Plateau (51 species) and Bambuli wetland (44 species) also had a good number of diversity in terms of species. Out of 65 species, *Agriocnemis keralensis*, *Ceriagrion chromothorax*, and *Bradinopyga konkanensis* are endemic to the Western Ghats (Table 3). Out of 65 species, 57 are LC (Least Concern), three are DD (Data deficient), and five are NE (Not Evaluated) as per IUCN status.

Table 2. Family-wise distribution of Odonata of Thakurwadi & Bambuli wetlands and Chipi Plateau.

Family	No. of Species			Total
	Thakurwadi wetland	Bambuli wetland	Chipi Plateau	
Lestidae	2	0	3	3
Calopterygidae	2	1	1	2
Chlorocyphidae	2	0	2	2
Platycnemididae	2	1	2	2
Coenagrionidae	16	15	15	17
Aeshnidae	3	1	1	3
Gomphidae	1	1	2	2
Macromiidae	1	1	1	1
Libellulidae	28	24	24	33
Total	**57**	**44**	**51**	**65**

We report *Agriocnmeis keralensis* for the first time from Maharashtra and confirm record of *Gynacantha khasiaca* from Maharashtra. Three localities of *A. keralensis* in Sindhudurg are the northernmost record of the species which was previously known from Kerala and Goa (Image 8a). Out of the three localities, Thakurwadi and Bambuli are wetlands with moderate human interference. These two are major water sources to nearby human habitation in terms of farming. Third locality, Chipi plateau is a lateritic plateau near Arabian Sea and has many seasonal ponds. *G. khasiaca* was photographed in Sindhudurg District in October 2019 (Mujumdar et al. 2020) but further confirmation was not done due to lack of specimens. With this record from Majgaon, we confirm the presence of *G. khasiaca* in northern Western Ghats and report the range extension for the same (Image 8b). Majgaon is a village in Sawantwadi Taluka, surrounded by dense vegetation and some seasonal streams. With all these records, the rich biodiversity of Sindhudurg District is again highlighted. Yet there are many remote and inaccessible

Table 3. Combined checklist of Odonata of Thakurwadi & Bambuli wetlands and Chipi Plateau.

	Scientific name	Authority	IUCN status	Location		
				Thakur-wadi Wetland	Bambuli Wetland	Chipi Plateau
	Suborder Zygoptera Selys, 1854					
	Family Lestidae Calvert, 1901					
01	*Lestes elatus*	Hagen in Selys, 1862	LC	✓	—	✓
02	*Lestes praemorsus*	Hagen in Selys, 1862	LC	✓	—	✓
03	*Lestes viridulus*	Rambur, 1842	LC	—	—	✓
	Family Calopterygidae Selys, 1850					
04	*Vestalis apicalis*	Selys, 1873	LC	✓	✓	—
05	*Vestalis gracilis*	(Rambur, 1842)	LC	✓	—	✓
	Family Chlorocyphidae Cowley, 1937					
06	*Heliocypha bisignata*	(Hagen in Selys, 1853)	LC	✓	—	✓
07	*Libellago indica*	(Fraser, 1928)	NE	✓	—	✓
	Family Platycnemididae Yakobson & Bainchi, 1905					
08	*Copera marginipes*	(Rambur, 1842)	LC	✓	✓	✓
09	*Copera vittate*	Selys, 1863	LC	✓	—	✓
	Family Coenagrionidae Kirby, 1890					
10	*Aciagrion occidentale*	Laidlaw, 1919	LC	✓	✓	—
11	*Agriocnemis keralensis*[*#]	Peters, 1981	LC	✓	✓	✓
12	*Agriocnemis pieris*	Laidlaw, 1919	LC	✓	✓	✓
13	*Agriocnemis pygmaea*	(Rambur, 1842)	LC	✓	✓	✓
14	*Agriocnemis splendidissima*	Laidlaw, 1919	LC	✓	✓	✓
15	*Ceriagrion cerinorubellum*	(Brauer, 1865)	LC	✓	✓	✓
16	*Ceriagrion chromothorax*[*]	Joshi & Sawant, 2019	NE	✓	✓	✓
17	*Ceriagrion coromandelianum*	(Fabricius, 1798)	LC	✓	✓	✓
18	*Ceriagrion olivaceum*	Fraser, 1924	LC	✓	✓	—
19	*Ceriagrion rubiae*	Laidlaw, 1916	NE	✓	✓	✓
20	*Ischnura rubilio*	Selys, 1876	NE	✓	✓	✓
21	*Ischnura senegalensis*	(Rambur, 1842)	LC	✓	—	✓
22	*Mortonagrion varralli*	Fraser, 1920	DD	✓	✓	✓
23	*Pseudagrion decorum*	(Rambur, 1842)	LC	—	—	✓
24	*Pseudagrion malabaricum*	Fraser, 1924	LC	✓	✓	✓
25	*Pseudagrion microcephallum*	(Rambur, 1842)	LC	✓	✓	✓
26	*Pseudagrion rubriceps*	Selys, 1876	LC	✓	✓	✓
	Family Aeshnidae Leach, 1815					
27	*Anax guttatus*	(Burmeister, 1839)	LC	✓	✓	✓
28	*Gynacantha dravida*	Lieftinck, 1960	DD	✓	—	—
29	*Gynacantha khasiaca*[#]	MacLachlan, 1896	DD	✓	—	—
	Family Gomphidae Rambur, 1842					
30	*Ictinogomphus rapax*	(Rambur, 1842)	LC	✓	—	✓
31	*Paragomphus lineatus*	(Selys, 1850)	LC	—	✓	✓
	Family Macromiidae Needham, 1903					
32	*Epophthalmia vittata*	Burmeister, 1839	LC	✓	✓	✓
	Family Libellulidae Leach, 1815					
33	*Acisoma panorpoides*	Rambur, 1842	LC	✓	—	✓
34	*Brachydiplax sobrina*	(Rambur, 1842)	LC	✓	✓	✓
35	*Brachythemis contaminata*	(Fabricius, 1793)	LC	✓	✓	✓
36	*Bradinopyga geminata*	(Rambur, 1842)	LC	✓	✓	✓
37	*Bradinopyga konkanensis*[*]	Joshi & Sawant, 2020	NE	—	—	✓
38	*Cratilla lineata*	(Brauer, 1878)	LC	✓	✓	—

	Scientific name	Authority	IUCN status	Location		
				Thakur-wadi Wetland	Bambuli Wetland	Chipi Plateau
39	*Crocothemis servilia*	(Drury, 1770)	LC	✓	✓	✓
40	*Diplacodes lefebvrii*	(Rambur, 1842)	LC	✓	—	—
41	*Diplacodes nebulosa*	(Fabricius, 1793)	LC	✓	✓	✓
42	*Diplacodes trivialis*	(Rambur, 1842)	LC	✓	✓	✓
43	*Hydrobasileus croceus*	(Brauer, 1867)	LC	✓	✓	✓
44	*Indothemis carnatica*	(Fabricius, 1798)	LC	—	✓	✓
45	*Indothemis limbata sita*	Campion, 1923	LC	✓	—	—
46	*Lathrecista asiatica*	(Fabricius, 1798)	LC	✓	✓	—
47	*Neurothemis fulvia*	(Drury, 1773)	LC	✓	—	—
48	*Neurothemis intermedia*	(Rambur, 1842)	LC	✓	—	✓
49	*Neurothemis tullia*	(Drury, 1773)	LC	✓	—	—
50	*Orthetrum luzonicum*	(Brauer, 1868)	LC	✓	✓	✓
51	*Orthetrum chrysis*	(Selys, 1891)	LC	✓	✓	✓
52	*Orthetrum glaucum*	(Brauer, 1865)	LC	✓	—	—
53	*Orthetrum pruinosum*	(Burmeister, 1839)	LC	✓	✓	✓
54	*Orthetrum sabina*	(Drury, 1770)	LC	✓	✓	✓
55	*Pantala flavescens*	(Fabricius, 1798)	LC	✓	✓	✓
56	*Potamarcha congener*	(Rambur, 1842)	LC	✓	—	✓
57	*Rhodothemis rufa*	(Rambur, 1842)	LC	✓	✓	✓
58	*Rhyothemis variegata*	(Linnaeus, 1763)	LC	✓	✓	✓
59	*Tetrathemis platyptera*	Selys, 1878	LC	—	✓	—
60	*Tholymis tillarga*	(Fabricius, 1798)	LC	✓	✓	✓
61	*Tramea limbata*	(Desjardins, 1832)	LC	✓	✓	✓
62	*Trithemis aurora*	(Burmeister, 1839)	LC	✓	✓	✓
63	*Trithemis festiva*	(Rambur, 1842)	LC	✓	✓	✓
64	*Trithemis pallidinervis*	(Kirby, 1889)	LC	—	✓	✓
65	*Urothemis signata*	(Rambur, 1842)	LC	—	✓	—

* Species endemic to Western Ghats | # New records for the Maharashtra State | NE—Not Evaluated | DD—Data deficient | LC—Least Concern

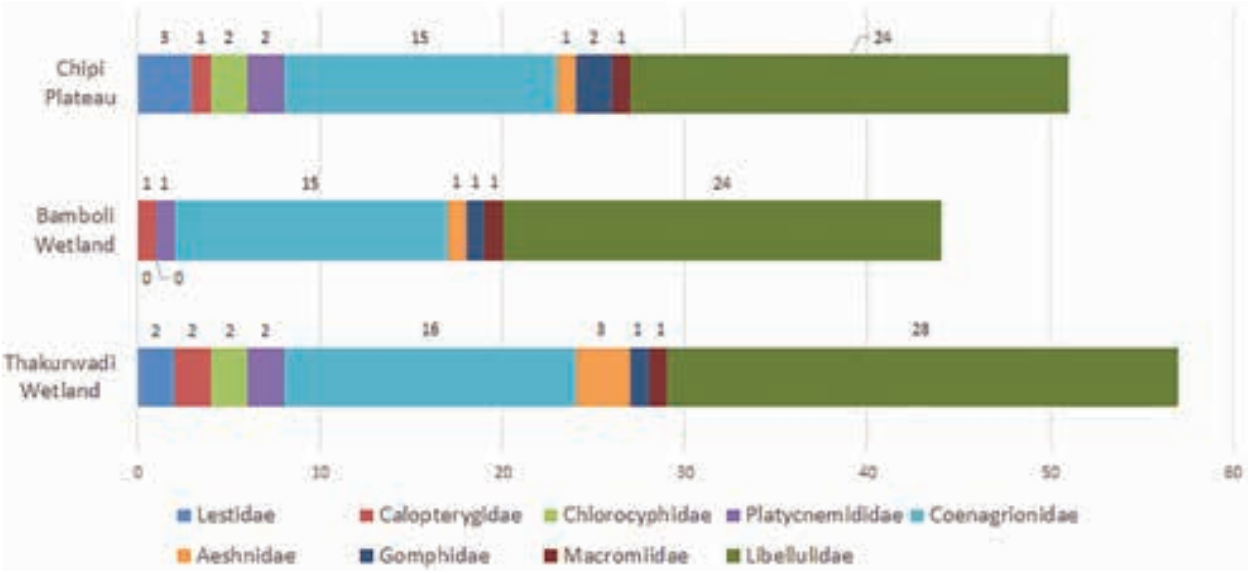

Figure 1. Graphical representation of family-wise distribution of Odonata in Thakurwadi & Bambuli wetlands and Chipi Plateau.

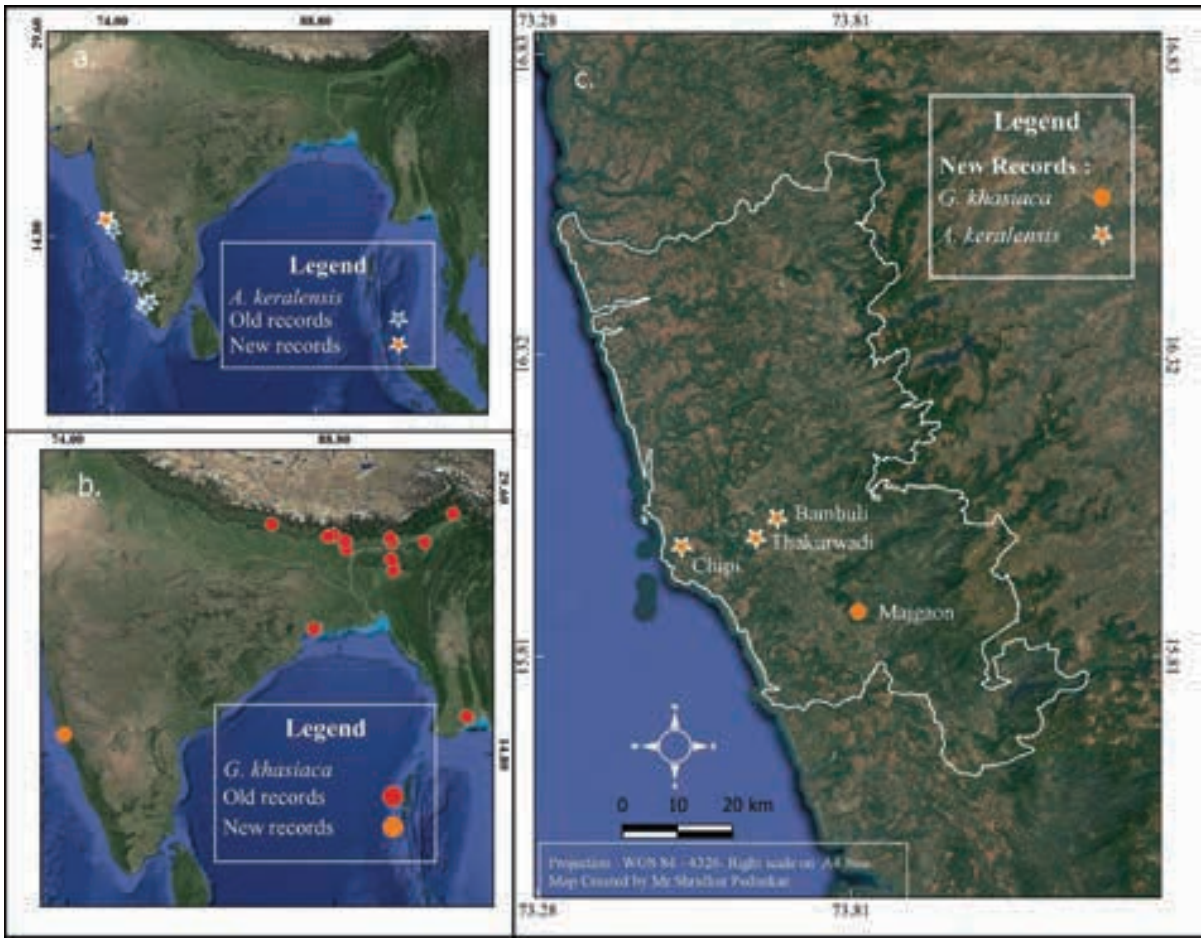

Image 8. Maps depicting the known distribution of: a—*Agriocnemis keralensis* (Peters, 1981) | b—*Gynacantha khasiaca* (MacLachlan, 1896) | c—Map of Sindhudurg District with distribution of *A. keralensis* and *G. khasiaca*.

locations in the district, which may reveal new records in terms of biodiversity. Hence, systematic surveys of such areas should be conducted for documentation of biodiversity so that long term measures for conserving the habitats can be taken effectively.

Sindhudurg District is one of the richest biodiversity hotspots in India. But there are many threats to the environment due to manmade activities. Rampant deforestation in the foothills of the Sahyadri range, monoculture farming, raw mining on lateritic plateaus, excessive sand mining in river beds are major threats which are causing habitat destruction. Wetlands like Thakurwadi and Bambuli are rich in terms of not only Odonata fauna but also other organisms. There is an immediate need to conserve such wetlands and other water bodies for long term benefits to humans and other organisms. Plateaus like Chipi are unique lateritic plateaus and are facing habitat disturbances due to raw mining, constructions of houses, and roads. The current checklist of Odonata from these localities shows the richness of biodiversity and highlights the need for effective conservation measures.

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Image 9. Field images of: a—*Lestes praemorsus* (Selys, 1862) male | b—*Heliocypha bisignata* (Hagen, 1853) male | c—*Copera marginipes* (Rambur, 1842) male | d—*Aciagrion occidentale* (Laidlaw, 1919) male | e—*Ceriagrion cerinorubellum* (Brauer, 1865) copula | f—*Ceriagrion chromothorax* (Joshi & Sawant, 2019) male | g—*Gynacantha dravida* (Lieftinck, 1960) male | h—*Ictinogomphus rapax* (Rambur, 1842) male | i—*Epophthalmia vittata* (Burmeister, 1839) male | j—*Indothemis limbata sita* (Selys, 1891) male immature | k—*Trithemis aurora* (Burmeister, 1839) male | l—*Trithemis festiva* (Rambur, 1842) male. © a, e, f, h, j, k, l—Dattaprasad Sawant, © c, d—Yogesh Koli, © b, g, i—Akshay Dalvi.

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SHORT COMMUNICATION

A new distribution record of the Horn Coral *Caryophyllia grandis* Gardiner & Waugh, 1938 (Anthozoa: Scleractinia) from the Karnataka Coast, India

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Abstract: Surveys were conducted under the project entitled "Resource exploration and Inventorisation of Deep Sea ecosystem & Marine ecosystem Dynamics: Sagar Sampada Cruise" by on-board FORV *Sagar Sampada Cruise* No. 374 from 2 April to 15 April 2018 from Okha to Cochin along the west coast of India. The species *Caryophyllia (Caryophyllia) grandis* is recorded from a depth of 580m off Karwar, Karnataka and is reported herein as a new distribution record to the Karnataka coast, India.

Keywords: Azooxanthellate coral, Scleractinian coral, west coast.

Scleractinian corals are represented by 627 species in India of which 35 species are azooxanthellate coral, among them nine species belonging to the genus *Caryophyllia* Lamarck, 1801 (Mondal et al. 2016). The genus *Caryophyllia* belongs to the family Caryophylliidae, order Scleractinia, suborder Hexacorallia, and commonly called azooxanthellate corals or deep-sea corals. The family Caryophylliidae is one of the 40 presently recognized families of the order Scleractinia (WoRMS 2021) which globally includes more than 300 species belonging to 42 genera (Cairns 1999) of which 90% of azooxanthellate corals and 10% of zooxanthellate corals were reported around the world (Reyes et al. 2009). In the Indian Ocean, 86 species belonging to the family Caryophylliidae have been reported by Cairns (1999). Among them, 44 species of azooxanthellate corals were reported along the Indian coast (Venkataraman et al. 2003; Venkataraman 2006). A total of 10 species of coral belonging to the genus *Caryophyllia* was reported from Indian waters, of which five species were reported by Alcock (1898) three species by Venkataraman (2007) and three species by Lazarus & Chandran (2016). The present study gives a detailed description of the species *Caryophyllia (Caryophyllia) grandis* collected off Karwar, Karnataka coast, India.

Materials And Methods

The present survey was conducted from 2 to 15 April 2018, along the west coast from Okha (Gujarat) to Cochin (Kerala) by on-board the fisheries and oceanographic research vessel FORV Sagar Sampada Cruise No. 374. The specimens examined in the present study were collected by a trawl fishing operation at about 580m depth off Karnataka (14.376^{0}N, 73.027^{0}E), west coast of India. The specimens were examined and identified under a Leica M205 stereo-zoom microscope (Cairns &

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Image 1. Study area with type locality of *Caryophyllia* (*Caryophyllia*) *grandis* Gardiner & Waugh, 1938 from the Maldives. (Map from https://www.geoplaner.com/ A—Indian coast site | B—Maldives Islands)

Kitahara 2012) and both examples photographed using a Nikon Coolpix W300 camera. The voucher specimens are deposited in the National Zoological Collection, ZSI, MARC, Digha, Reg. No. C5498.

Results

A total of nine species belonging to the genus *Caryophyllia* has been reported from India (Table 1). Among them, seven species were reported from the Andaman & Nicobar Islands, five species from Lakshadweep Islands, one species each off the Madras and Kerala coast. *Caryophyllia (Caryophyllia) grandis* was observed for the first time from the Karwar coast, Karnataka, India. A detailed description of this species is given below.

Systematic description

Phylum Cnidaria Verrill, 1865
Class Anthozoa Ehrenberg, 1834
Subclass Hexacorallia Haeckel, 1896
Order Scleractinia Bourne, 1900
Suborder Caryophylliina Vaughan & Wells, 1943
Family Caryophylliidae Dana, 1846
Genus *Caryophyllia* Lamarck, 1801
Caryophyllia (Caryophyllia) grandis Gardiner & Waugh, 1938 (Image 1 & 2).
Common Name: Horn Coral

Materials examined: Reg. No. C5498, two samples from soft clay and fine sand bottom, off Karwar coast (14.376^{0}N, 73.027^{0}E) Karnataka, west coast of India, Arabian Sea at 580m depth; coll. J.S. Yogesh Kumar.

Diagnosis: Both specimens are curved horn-shaped and free-living. One large specimen corallum is 38mm in size of Greater Calicular Diameter (GCD) and the average height of the corallum is 35mm. The septa are arranged hexamerally in five complete cycles (S1–S5); however, one large specimen 38mm GCD has 24 primary septa and a total of 96 septa (Image 2A left). The second specimen 33mm GCD has 22 primary septa and a total of 88 septa (Image 2A right). The septa S3 are slightly less exsert than primary septa (S1) and a total 24 and 22 paliform lobes are in both specimens, respectively. The paliform are narrower than S4 and border form a crown circling a fascicular columella. The columellar are composed of broad and twisted elements in the centre part of the corallites.

Type locality: West side of Fadiffolu Atoll, Maldive Islands at 494m depth (14.978^{0}N, 73.273^{0}E) Reg. No. BM1950.1.9.211-225 (Cairns & Zibrowius 1997; Kitahara et al. 2010)

Distribution: Maldive (494m), western Australia (399–431 m), Indonesia (251–567 m); South Africa to western Sumatra (183–595 m).

Taxonomical Reference: Veron (1986); Cairns & Keller (1993); Cairns & Zibrowius (1997); Cairns et al. (1999); Kitahara et al. (2010).

Remark: *Caryophyllia (Caryophyllia) grandis* is closely related to *Caryophyllia (Caryophyllia) ambrosia* Alcock, 2007 (Laccadive, 1,000–1,070 fms).

Table 1. List of the species under the genus *Caryophyllia* Lamarck, 1801 as per the World Register of Marine Species (WoRMS).

	Reported name of the species	AN	LAK	KL	TN	KN	Ref.	Status
	Family Caryophyllidae Dana, 1846 Genus *Caryophyllia* Lamarck, 1801							
1.	*Caryophyllia* (*Acanthocyathus*) *grayi* (Milne Edwards & Haime, 1848)	*					I	Accepted
2.	*Caryophyllia* (*Caryophyllia*) *ambrosia* Alcock, 1898		*				II	Accepted
3.	*Caryophyllia* (*Caryophyllia*) *clavus* Scacchi, 1835 Accepted name: *Caryophyllia* (*Caryophyllia*) *smithii* Stokes & Broderip, 1828	*	*				III	Synonymised
4.	*Caryophyllia* (*Caryophyllia*) *ephyala* Alcock, 1891	*	*				II	Accepted
5.	*Caryophyllia* (*Caryophyllia*) *grandis* Gardiner & Waugh, 1938	+	+			**	I	Accepted
6.	*Caryophyllia* (*Caryophyllia*) *paradoxus* Alcock, 1898			*			II	Accepted
7.	*Caryophyllia arcuata* Milne Edwards & Haime, 1848	*	*				I, III	Accepted
8.	*Caryophyllia communis* (Seguenza, 1863) (fossil species)	*					II	Accepted
9.	*Caryophyllia scillaeomorpha* Alcock, 1894 Accepted name: *Caryophyllia* (*Caryophyllia*) *ambrosia* Alcock, 1898				*		II	Synonymised

*—Reported | **—present study report | +—doubtful | AN—Andaman & Nicobar | LAK—Lakshadweep | KL—Kerala | TN—Tamil Nadu | KN—Karnataka | Ref.—Reference | I—Venkataraman (2007) | II—Alcock (1898) | III—Lazarus & Chandran (2016).

Discussion

Azooxanthellate corals are reported from deep water and dark environments (Dinesen 1982, 1983). Nearly 34 species of azooxanthellate corals are known from the seas around the Indian waters (Turner et al. 2001). Venkataraman (2007) reported updated checklist of azooxanthellate corals from the Indian coast. Recently, Lazarus & Chandran (2016) listed a total of 34 species belonging to 17 genera, four families from the Indian coast; of which 20 species were reported from the Andaman & Nicobar Islands, 13 species from the Gulf of Mannar, 12 species from the south-west coast of India, four species each from the Gulf of Kachchh, Lakshadweep, and 3 species from the mid-west coast (Goa). The species *Caryophyllia (Caryophyllia) grandis* was excluded in the updated list of azooxanthellate corals from the Indian coast (Lazarus & Chandran 2016).

In India, a total of nine species of coral belonging to the genus *Caryophyllia* were reported (Alcock 1898; Venkataraman 2007; Lazarus & Chandran 2016). The species name verified in the WoRMS database, of which seven species status showed accepted and two species synonymised (Table 1). The present study reported *Caryophyllia (Caryophyllia) grandis* azooxanthellate coral from Karwar, west coast of India and close to type locality Maldives (Image 1). The species was first described by Gardiner & Waugh (1938) from the Maldives at 494m depth followed by this species was reported from Australia at 431m depth, Indonesia at 567m depth, and South Africa to Western Sumatra at 595m depth (Cairns 1991; Cairns & Keller 1993; Cairns & Zibrowius 1997; Cairns 1998, 1999, 2004). Kitahara et al. (2010) reported the same species from Australian waters, and the size of the corallum is 50mm GCD and curved. The upper theca was white and the lower theca was discoloured. The present reported species, corallum is 39–40 mm in size, horn-shaped and lower thecas are pale white. The species *Caryophyllia (Caryophyllia) grandis* is the first distribution report from off Karwar coast, Karnataka, India.

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Image 2. ***Caryophyllia*** **(*Caryophyllia*)** ***grandis*****: A—Entire specimen | B—View of corallum | C—Lateral view of exsert septa and costa | D—Oblique view | E, F—Calicular views | G—Septa | H—Columella. © J. S. Yogesh Kumar.**

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OPEN ACCESS

SHORT COMMUNICATION

Re-collection, extended distribution, and amplified description of *Vaccinium paucicrenatum* Sleumer (Ericaceae) from the Arunachal Himalaya in India

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Abstract: *Vaccinium paucicrenatum* Sleumer has been re-collected from three different districts of Arunachal Pradesh approximately after 91 years subsequent to I.H. Burkill's collection (no. 36976, K) from Ripsing of outer Abor Hills (presently a part of East and West Siang districts nearby Pashighat area) of Arunachal Pradesh on 8 March, 1912. Due to poor description by the earlier workers, the present paper provides amplified description based on field and herbarium data including leaf anatomy (leaf stomata and vein-islets), detailed extended distribution, live and herbarium images and distribution map for easy identification in the field.

Keywords: Arunachal Pradesh, leaf anatomy, northeastern India.

The genus *Vaccinium* L., consisting of about 140 species (Mabberley 2008), is distributed in tropical Asia, Europe, southeastern Africa, Madagascar, and north and south America. Of these, 28 species are reported to occur in India (Panda & Sanjappa 2014) and are distributed in the eastern Himalaya, northeastern India (except Tripura) and the hill tops of the southern Western Ghats.

vander Kloet et al. (2003), merged Airy Shaw's new species, *Vaccinium setipes*, under *V. paucicrenatum* Sleumer in *Vaccinium* sect. *Aethopus* Airy Shaw based on average-linkage dendrogram calculated from raw data for 76 *Vaccinium* OTU's (Operational Taxonomic Unit) using the dissimilarity form of Gower's co-efficient for mixed data, principal coordinates analysis, and partitioning analysis (vander Kloet et al. 2003). They re-circumscribed *Vaccinium* sect. *Aethopus* Airy Shaw not only merging *V. setipes* under *V. paucicrenatum* but also included other four species as valid and another four species as synonyms under these valid species transferring from *Vaccinium* sect. *Vitis-idaea* (Moench) W.D.J. Koch. These species are *V. nummularia* Hook.f. & Thomson ex C.B. Clarke (*V. chaetothrix* Sleumer as a synonym), *V. retusum* (Griff.) Hook.f. ex C.B. Clarke (*V. haitangense* Sleumer as a synonym), *V. moupinense* Franch. (*V. dendrocharis* Hand.-Mazz. and *V. merrillianum* Hayata as synonyms), and *V. delavayi* Franch.

Shaw (1948) erected a new species, *V. setipes*, from "Assam population of outer Abor Hills, Ripshing" (Arunachal Pradesh in India) of *V. paucicrenatum* Sleumer based on I.H. Burkill collection (no. 36976, K photo!) which was cited by Sleumer (1941) as *V. paucicrenatum* in the protologue. Shaw (1948) distinguished "Assam"

Editor: Anonymity requested.

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population of *V. paucicrenatum* as *V. setipes* due to the presence of unique hispid-setose pedicels and axillary fascicled raceme which are not found in *V. paucicrenatum* Sleumer. Therefore, Shaw (1948) erected a new species, *V. setipes* under *Vaccinium* sect. *Aethopus* Airy Shaw.

As a result of taxonomic revisionary work on the Indian Ericaceae under "Flora of India Project" of the Botanical Survey of India (1999–2004), as well as other national projects (UGC) on Indian Ericaceae (2009–2011) and a project (2014–16) to supervise national scholar (Rajiv Gandhi Fellow, UGC), extensive field visits were done during these periods at different localities of the eastern Himalaya including a major part of Arunachal Pradesh by the author.

From the visits, specimens from three interesting epiphytic *Vaccinium* populations from three different districts of Arunachal Pradesh were collected on 24 April 2003 from Lohit (S. Panda 30881, CAL), 25 February 2010 from Kurung Kumey (S.S. Dash 31690, ARUN-Aruncahal Pradesh Herbarium, Botanical Survey of India at Itanagar), and 21 November 2014 from Lower Subansiri (S. Panda, P. Roy & D.S. Mahanty, 55, DGC-Darjeeling Govt College Herbarium). Number of individual plants were counted at Lohit population (7) and Lower Subansiri population (6). Based on these exomorphological and leaf anatomical data, specimens of *Vaccinium* L. are identified as *V. paucicrenatum* Sleumer. According to Airy shaw (1948), *V. paucicrenatum* was not reported from India. But according to vander Kloet et al. (2003), *V. paucicrenatum* had been reported by Sleumer (1941) based on I. H. Burkill collection (no. 36976, K) from Outer Abor Hills in 1912.

Materials and Methods

The present work is the result of an extensive field visit in different districts of Arunachal Pradesh in 2003–2014 as well as herbarium consultations in Indian herbaria (CAL, DD, ASSAM, ARUN). This work also recorded GPS points (used GARMIN eTrex 10 model) data (latitude-longitude and altitudes) during field visits. The work was carried out partly in Central National Herbarium (Voucher specimen deposited: S. Panda 30881: Lohit population) and partly in the laboratory of Angiosperm Taxonomy & Ecology, Barasat Govt College (S. Panda 30881: Lohit population-leaf anatomy), Darjeeling Govt. College (Lower Subansiri Population

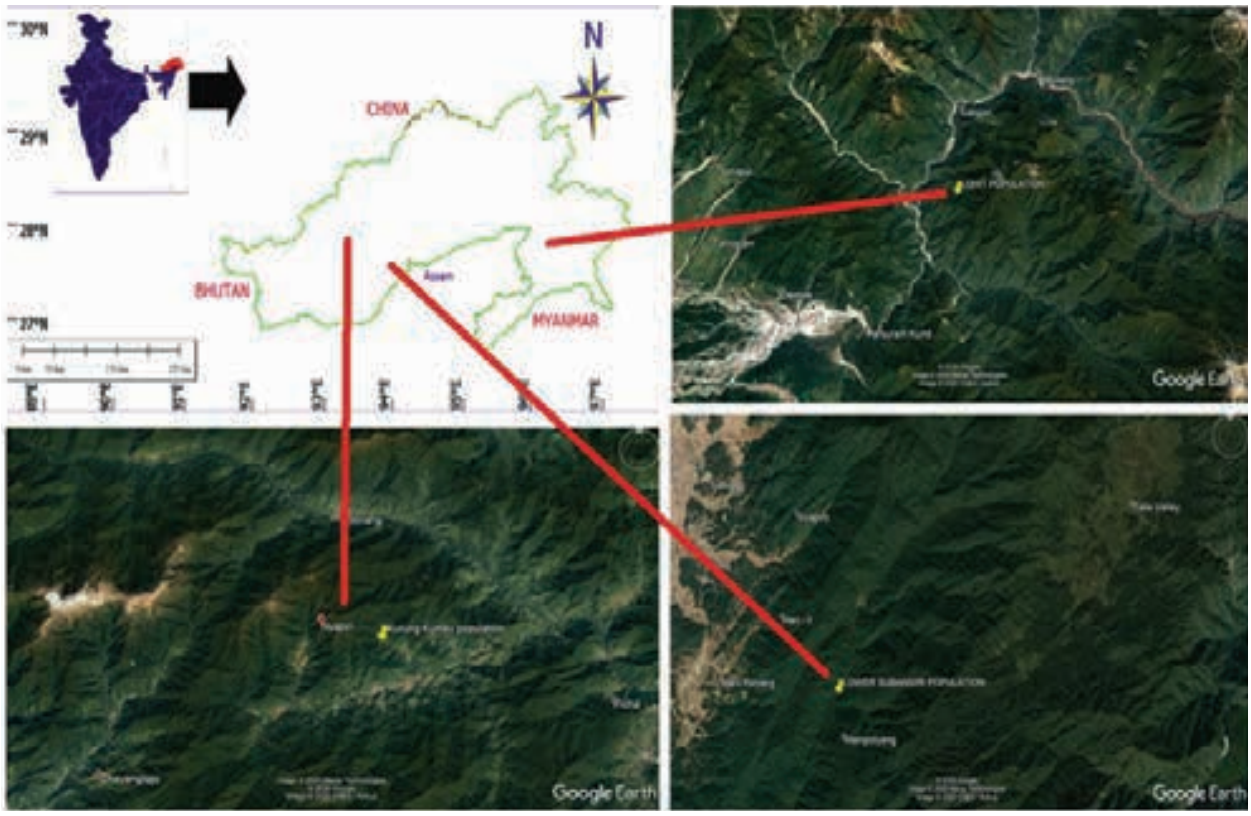

Image 1. Distribution of *Vaccinium paucicrenatum* Sleumer in Arunachal Himalaya in India (collection sites of Kurung Kumey, Lower Subansiri and Lohit districts with magnified Google Earth imagery). Indian map with Arunachal Pradesh <www.maphill.com>.

Panda et al. 55: Darjeeling Govt College Herbarium). Fruiting materials of *V. paucicrenatum* belonging to S.S. Dash 31690 (ARUN: Arunachal Herbarium, Botanical Survey of India) was consulted in November, 2014 at Arunachal Herbarium by the author. Botanical identity was confirmed with consultation of Type images (BM!; K!) as well as consultation of relevant literature including protologue. Amplified description of *V. paucicrenatum* is based on all three field collections (S. Panda 30881, S.S. Dash 31690, & S Panda et al. 55) as well as type images (Kingdon-Ward 13560, BM; Burkill 36976, K).

Stomatal slide preparation

Small cubical pieces of leaf blades were excised from the base, middle and apex. Several existing methods viz., 10% HNO_3-boiling for 10 minutes, 5% KOH overnight (12–24 hours) treatment without boiling and with boiling were done. Pieces were ringed in sterilized water until clear. After clearing, pieces were dehydrated in an ethanol series followed by staining with 10% safranin and mounted onto a microscope slide in DPX (pieces of basal, middle and apical regions on one slide). The slide was examined under Olympus (Tokyo: Model no. SAI740) light microscope using 10X and 40X objectives and camera lucida drawings were made with the help of a drawing prism. The slides (5 for each) are deposited in the Laboratory of Angiosperm Taxonomy, Post Graduate Department of Botany, Barasat Government College (2010) & Darjeeling Govt College (2016). The descriptive terminology follows Dilcher (1974) and Carpenter (2005).

Methodology of leaf clearing for venation study (areoles)

Entire mature leaves were immersed in 2.5% NaOH solution until clear (closed condition). In the present study, most of the leaves were cleared after eight days of NaOH treatment. After eight days, these NaOH-treated leaf samples were again immersed in 2.5% NaOH solution for 2–3 days followed by one drop chloral hydrate treatment overnight. Leaf samples were then washed in distilled water. After clearing, one good sample (entire leaf) was dehydrated in an ethanol series followed by staining with 1% safranin and mounted onto a microscope slide in DPX (entire leaf in one slide). The slides are deposited in the laboratory of Angiosperm Taxonomy, PG Department of Botany, Barasat Govt. College (2010) & Darjeeling Govt College (2016). The descriptive terminology follows Hickey (1973) and Dilcher (1974).

Taxonomic treatment and amplified description

***Vaccinium paucicrenatum* Sleumer**
(Images 1–5; Figure 1)

in Engl., *Bot. Jahrb. Syst*. 71(4): 432–433. 1941; Merrill, *Brittonia* 4(1): 157. 1941; Airy Shaw, *Kew Bull*. 1948: 246. 1948; vander Kloet et al., *Acta Bot. Yunnanica* 25(1): 21. 2003; Panda & Sanjappa in Sanjappa & Sashtri, Fasc. Fl. India (Ericaceae) no. 25: 399–400. 2014. Type: Northern Myanmar, Nam Tamai valley, hills east of Putao, 27.753^{0}N & 97.500^{0}E, 1600 m, 09.xii.1937, Kingdon-Ward 13560 (BM, photo!).

Epiphytic trailing profusely branched shrub to 1m high; growing on a fallen *Quercus* tree with irregularly lobed basal lignotubers which are 5–7 × 4.5–6.5 cm, glabrous, pale brown; each lobe of lignotuber appearing like a potato tuber. Stem glabrous, lenticellate; old branches beset with sparsely blackish hispid-setose hairs while current season's branches (young twigs) beset with dense brown hispid-setose hairs (up to 4mm long), terete. Leaves closely appressed to branches, alternate to sub-opposite, lamina usually ovate-elliptic to elliptic (but Lohit population-S. Panda 30881 showed usual elliptic to rarely ovate-elliptic shape), 10–16 × 6–10 mm (Kurung Kumey-S.S. Dash 31690 and Abor Hill-Burkill 16976) populations showed larger leaves viz., 13–16 × 7–10.5 mm and 12–15 × 7–10 mm respectively, while Lohit population- S. Panda 30881 showed smaller leaves 9–13 × 7–9 mm), obscurely serrate at margin (5–6 obscure teeth on each side), serration found only on upper 3/4th half but basal 1/4th half entire, usually apiculate to rarely acute at apex (Lohit population S. Panda 30881 showed shortly acuminate apex, acumen up to 1mm long), broadly cuneate to subrotundate at base, glabrous on both surfaces, dark green and shiny adaxially while light green abaxially, apical leaves of current season's greenish with purple-red; venation conspicuously brochidodromous with 2–3 pairs of lateral veins, prominent on both surfaces, thinner veins adaxially but comparatively thicker abaxially (however, variations noticed in different populations, viz., Kurung Kumey population showed veins prominent adaxially and obscure abaxially; Lohit population showed veins prominent abaxially while obscure adaxially; Lower Subansiri population showed veins prominent on both surfaces including some leaves of adaxial surfaces showed obscure veins on the same branch). Petioles usually 1mm to rarely 1.5mm long; Lower Subansiri population showed petioles usually beset with tuft of brown hispid-setose hairs up to 3mm long, while dry herbarium materials showed glabrous or hair-scars on

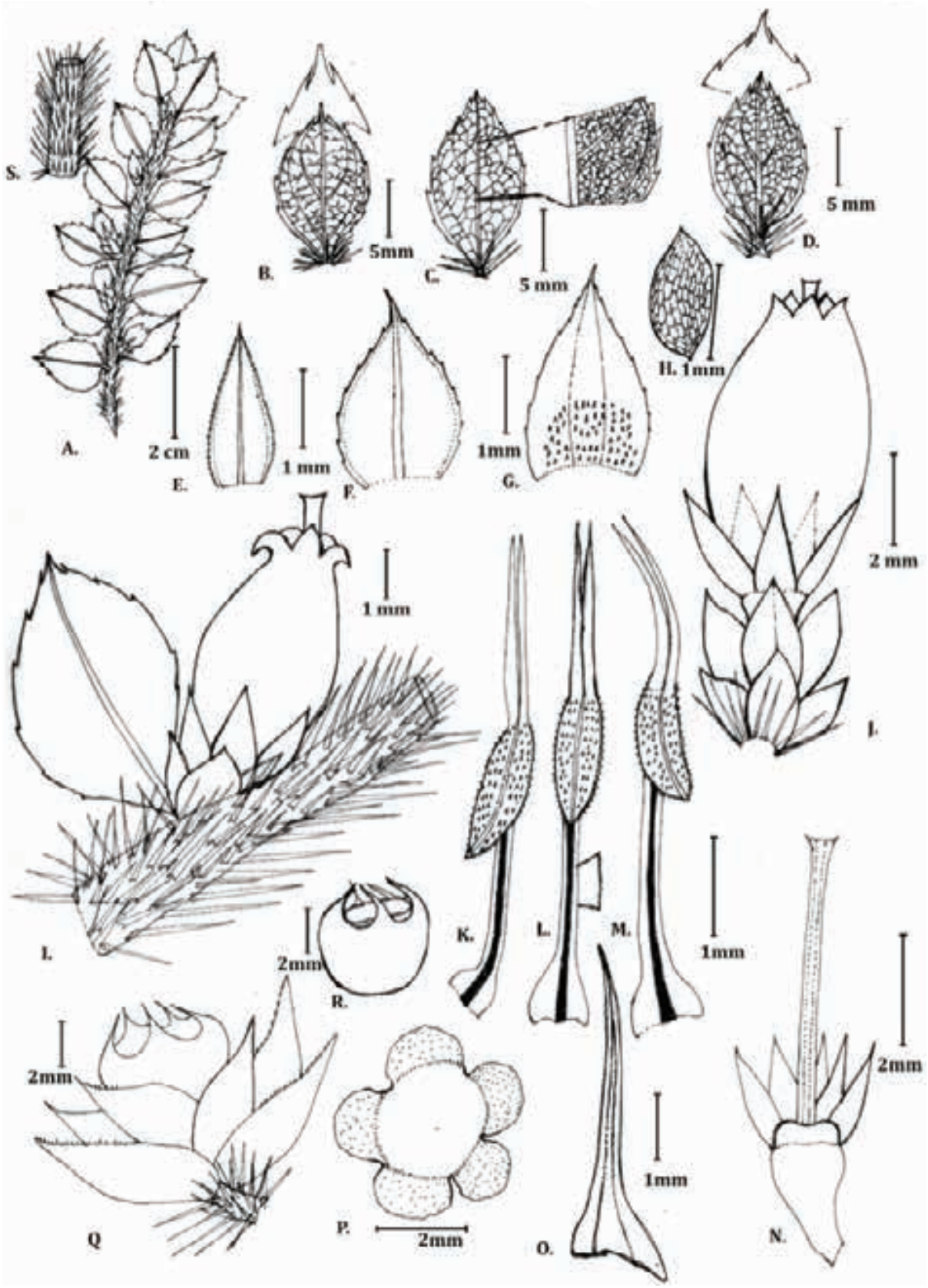

Figure 1. ***Vaccinium paucicrenatum*** **Sleumer: A—habit | B–D—leaves | E—calyx lobe | F–G—bracts | H—seed | I–J—flowers | K–M—stamens | N—pistil | O—stem hair | P—corolla lobes (top view) | Q–R—fruit | S—stem part magnified. Scale bars: (2cm—A), (5mm—B–D), (1mm—E–I, K–M, O), (2mm—J, N, P–R). Drawn from S. Panda et al. 55, DGC (A–P, S) and S.S. Dash 31690, ARUN(Q–R, H).**

Image 2 . Live images of *Vaccinium paucicrenatum* Sleumer: A–B—epiphytic habit on fallen Oak tree | C—close up of current season twig | D—habit with lignotubers (*S. Panda* et al. 55, DGC): Lower Subansiri, Arunachal Pradesh). © S. Panda.

petioles (may be due to deciduous nature of hairs which fall off in dry materials). Racemes almost absent or much reduced and flowers solitary, axillary from middle to subterminal parts of current season's branch. Flowers pentamerous, c. 10mm long including 2–3 mm long short pedicels which are light green, basally hispid-setose with a tuft of brown hairs and encircled by 6–8 brown-purple bracts. Bracts persistent in fruits, ovate-deltoid to broadly ovate, acuminate at apex, 2–3 × 1–1.5 mm, glabrous except basal part of dorsal surface puberulous, obscurely serrate at margin. Calyx purplish-red-white, obconical, persistent in fruits, c. 2.5mm long, glabrous, 5-lobed, basally connate, narrowly deltoid, 1.5–2 × 1 mm, shortly acuminate at apex. Corolla tubular-urceolate, white with longitudinal purple-red lines along 5-ridges, c. 6mm long (buds c. 4mm long), glabrous except apical lobes inside puberulous, 5-lobed, apical part 4mm in diam., each lobe minute or 0.5mm long, reflexed after anthesis, puberulous inside. Stamens 10, ecalcarate, c. 5mm long; filaments slender, light green, basally dilated, c. 1.5 mm long, glabrous, filament wall wavy at margin with a prominent median vertical vein

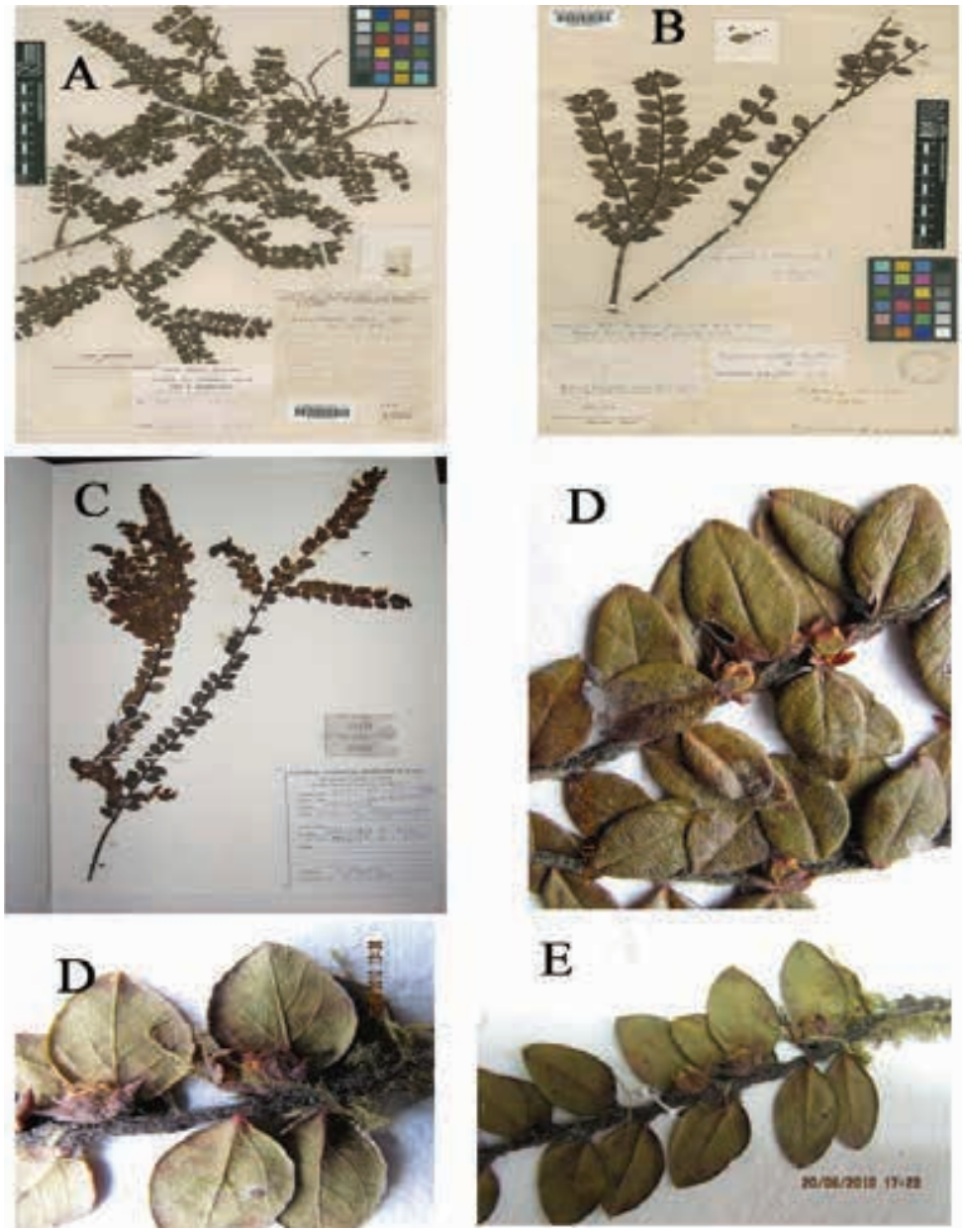

Image 3 . *Vaccinium paucicrenatum* Sleumer: A—original type image Nam Tamai Valley (Kingdon-Ward 13560, BM) | B—original type image Abor Hills (Burkill 36976, K) | C—S. Panda 30881, CAL (Lohit population) | D–F—fruiting twigs from Kurung Kumey (S.S. Dash 31690, ARUN). © S. Panda.

seen; anther lobes (thecae) oblong to linear-oblong, brown, c. 1.5mm long, verrucate, appendiculate (c. 0.5mm long at the base of thecae), at the apex of thecae c. 2mm long two linear pale yellow tubules seen. Pistil c. 8mm long; ovary glabrous, 1 × 1.5 mm, subglobose, light green, 5-locular on axile placentation; style filiform, light green, c. 5mm long, glabrous, obscure several vertical ridges seen, protruded up to 1mm out of mature flower; stigma truncate. Berries greenish with pinkish tinged apex and 3 × 2.5 mm (immature) to purple-black and 4 × 3.5 mm (mature), encircled with persistent 6–8 purple-brown bracts and five purple-red calyx. Seeds several, obconical, 1.5 × 1 mm, pale brown, scariosus. Floral formula: Br., Brl., ⊕ , ⚥, $K_{(5),}$ $C_{(5),}$ $A_{(10),}$ $\bar{}G_{(5).}$

Leaf anatomy: **Stomata** (Image 5G–I)**:** The study of Light Microscopic stomatal architecture (40X, 100X) includes number, form and arrangement of specialized epidermal cells associated with the stomatal guard cells. Stomata are distributed more or less evenly over the entire abaxial leaf surface in between the veins, but generally not over the finer veins and main veins. The stomata are uniformly distributed in abaxial surface only,

Image 4. *Vaccinium paucicrenatum* Sleumer: branches, flower, dissected floral parts of lowers Subansiri population (S. Panda et al. 55). © S. Panda.

they are widely separated from each other by epidermal cells.

Stomata type: The investigated species shows only one type, amphiparacytic (Dilcher 1974). Average dimension of stomata is 22.5 × 20 µm. Average dimension of guard cells: 10.3 × 2.4 µm. Epidermal cells are variable ranging from polygonal, pentagonal, rectangular to irregular and mostly isodiametric, some are elongated to deltoid. The epidermal walls in surface view are slightly arched to rarely straight. The epidermal walls in the adaxial surface are mostly straight. The maximum length of epidermal cell is 39.5µm and breadth is 22.5µm, while minimum length is 18µm and breadth is 14µm.

Leaf areoles (vein islets) (Image 5 A–F)**:** Quadrangular, pentagonal to rarely triangular in shape. Larger areole: 974 × 614 µm. Smaller areole: 374 × 112 µm. Areoles: 3 (average) per 1mm^2. Vein endings: 24 (average) per 1mm^2; veinlets simple unbranched to branched (once). Branched and unbranched veinlets occur in the same areole. Vein ends: pointed to bifurcated.

Extended distribution: India: Eastern Himalaya (Arunachal Pradesh: outer Abor Hills-Ripshing 1,676m (Adi dominated part of East and West Siang districts)); Lohit District between Tezu & Hayuliang 1,300m 27.972°N & 96.440°E; Lower Subansiri district-between Manipolyang & Pange 2,100m, 27.526°N & 93.899°E; Kurung Kumey district-above Nyapin 1,570m, 27.719°N & 93.375°E; N Myanmar (Burma-Tibet Frontier: Nam Tamai Valley, Hills east of Putao-899–1,600 m, 27.753^{0}N & 97.500^{0}E). vander Kloet et al. (2003) erroneously reported this species from China (SE Tibet) based on the specimen, Kingdon-Ward 9124 (BM, GH). However, Merrill (1941) and Airy Shaw (1948) reported this specimen from Nam Tamai Valley of N Myanmar.

Habitat: A trailing profusely branched epiphytic shrub up to 1m long growing in the higher branches in the canopy, mostly on *Quercus* trees at altitudes ranging from 1,295–2,126 m in Arunachal Himalaya while 899–1,600 m in the hills of Myanmar (Image 1).

Phenology: Flowering in early November to late January, peaking in late November to late December (but rarely in March in Abor Hill population collected by I.H. Burkill 36976). Fruiting: early February to late March, peaking in late February.

Specimens examined: 30881 (CAL, veg), India: eastern Himalaya: Arunachal Pradesh: Lohit District, 45km from Hayuliang toward Tezu, near Salangam, 1,300m, 27.972°N & 96.440°E, 24.iv.2003, coll. S. Panda; 55 (DGC, fl.), Lower Subansiri District, 4km from Manipolyang toward Pange, 2,125m, 27.526°N & 93.899°E, 21.xi.2014, coll. S. Panda et al.; 31690 (ARUN, fr), Kurung Kumey District, above Nyapin, 1,570m, 27.719°N & 93.375°E, 25.ii.2010, coll. S.S. Dash.

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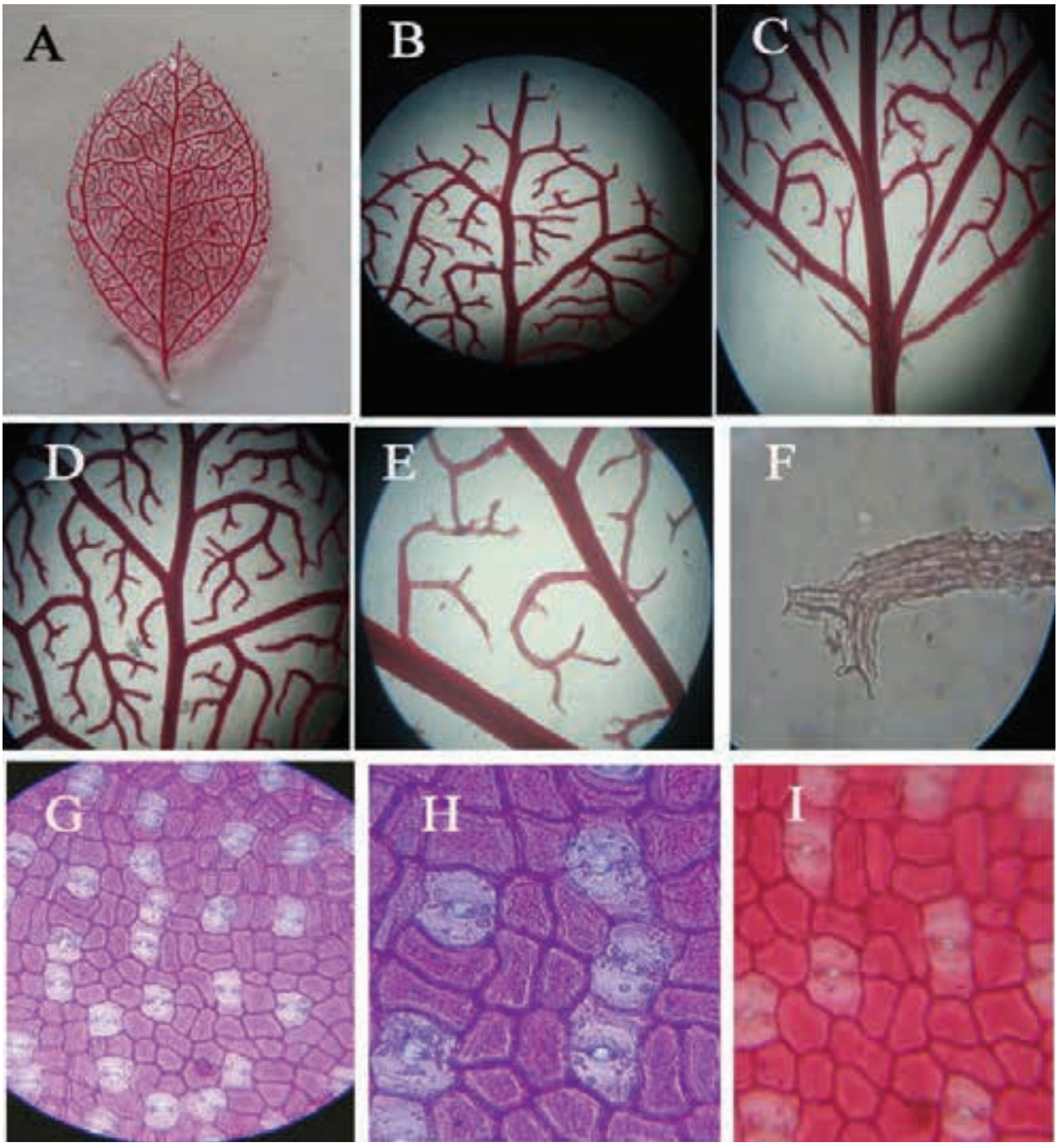

Image 5. Leaf anatomy of *Vaccinium paucicrenatum* Sleumer (S. Panda et al. 55, DGC): A—NaOH-treated entire leaf | B—leaf areole at apex (5X) | C—leaf areoleat base (5X) | D—leaf areole at middle (5X) | E—leaf areole at middle (10X) | F—vein ending (40X) | G–I—stomatal complex (40X) | H—stomatal complex (100X). © S. Panda.

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NOTE

SMALL WILD CATS SPECIAL SERIES

Photographic record of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in southern Western Ghats, India

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A Rusty-spotted Cat *Prionailurus rubiginosus* was photographed (Images 1,2) on 8 December 2018 in a dry deciduous forest in Walayar Reserve Forest, Palakkad district in the state of Kerala (Figure 1) during a survey on small carnivores. Camera traps with passive infra-red sensors and motion detectors were used for the study that lasted from 4 December 2018 to 10 January 2019. A total of 31 camera trap stations (Figure 1) were identified based on indirect evidence of small carnivores. The camera traps were installed at a height of 30cm from the ground and with a distance of at least 250m between two stations. They were kept active for 24 hours for 38 days with a total effort of 1,178 camera trap days.

The Walayar Reserve Forest extends over 125.65km^2, of which 30km^2 is dry deciduous habitat that we surveyed only. The major tree species in this dry deciduous patch include *Anogeissus latifolia, Alangium salvifolium, Careya arborea, Tectona grandis, Buchanania axillaris, Garuga pinnata, Cassia fistula, Strebulus asper, Holarhena pubescens*, and *Clerodendrum infortunatum*.

The other mammal species recorded by the camera traps during the study were Bonnet Macaque *Macaca radiata*, Tufted Grey Langur *Semnopithecus priam*, Asian Elephant *Elephas maximus*, Mouse Deer *Moschiola indica*, Barking Deer *Muntiacus muntjak*, Sambar Deer *Rusa unicolor*, Spotted Deer *Axis axis,* Gaur *Bos gaurus*, Wild Boar *Sus scrofa*, Common Palm Civet *Paradoxurus hermaphroditus*, Small Indian Civet *Viverricula indica*, Ruddy Mongoose *Herpestes smithii,* Stripe-necked Mongoose *Herpestes vitticollis*, Leopard Cat *Prionailurus bengalensis*, Tiger *Panthera tigris,* Leopard *P. pardus*, Dhole *Cuon alpinus*, Black-naped Hare *Lepus nigricollis*, and Indian Crested Porcupine *Hystrix indica*.

The Rusty-spotted Cat is a small felid that is endemic to India, Sri Lanka, and Nepal (Mukherjee et al. 2016). Along with the Black-footed Cat *Felis nigripes*, it is among the world's smallest cat species (Sunquist & Sunquist 2009). Since the Rusty-spotted Cat was recorded only once during the entire study period, we assume that it is rare in our study area. Our record of the Rusty-spotted Cat is consistent with its habitat use documented in eastern Gujarat (Patel 2006), Udanti-Sitanadi Tiger

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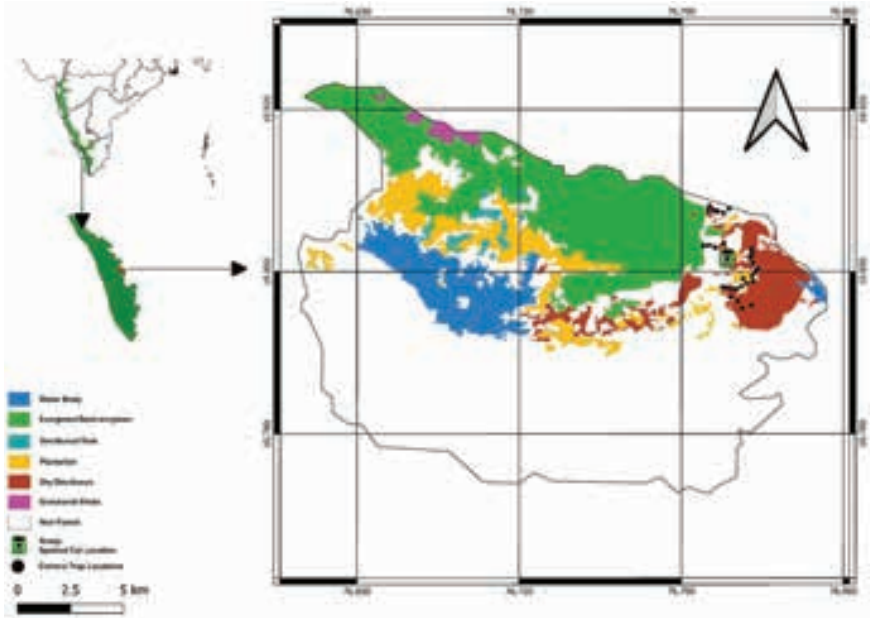

Figure 1. Location of Walayar Reserve Forest in Western Ghats, Kerala, India.

Image 1 & 2. Rusty-spotted Cat *Prionailurus rubiginosus* recorded in Walayar Reserve Forest on 8 December 2018. © Devika Sanghamithra & P.O. Nameer.

Image 3. A camera trap placed in the dry deciduous habitat in Walayar Reserve Forest. © Devika Sanghamithra & P.O. Nameer

Reserve in Chhattisgarh (Basak et al. 2018), Anaikatty Reserve Forest in Tamil Nadu (Mukherjee & Koparde 2014), and in the Aravalli Hills in Rajasthan (Sharma & Dhakad 2020; Singh & Kariyappa 2020). Elsewhere in India, it was also recorded in dry thorn forest, scrub forest, moist deciduous forest, semi-evergreen hill forest and sugarcane fields (Anwar et al. 2012; Kalle et al. 2013; Aditya & Ganesh 2016; Ghaskadbi et al. 2016; Bora et al. 2020; Chatterjee et al. 2020; Deshmukh et al. 2020; Sharma & Dhakad 2020; Silva et al. 2020).

In Kerala, it is present in Periyar Tiger Reserve, Parambikulam Tiger Reserve, Wayanad Wildlife Sanctuary, and Chinnar Wildlife Sanctuary (Shameer et al. 2019). The species is listed as 'Near Threatened' in the IUCN Red List of Threatened Species (Mukherjee et al. 2016) and is protected in India under Schedule I of the Wildlife (Protection) Act, 1972 (Acharjyo 1998). The Rusty-spotted Cat population is thought to decline by 20–25 % over the next three generations, primarily due to predicted habitat loss in central India (Mukherjee et al. 2016). The population is likely to be stable in protected areas; outside protected areas, it is threatened by diseases and road accidents (Mukherjee et al. 2016; Sharma & Dhakad 2020).

Our photographic record of the Rusty-spotted Cat in Walayar Reserve Forest is of interest as there are very few confirmed sightings of this species in Kerala. All the previous records in Kerala were obtained in dry deciduous forests (Shameer et al. 2019), and the present record also supports the Rusty-spotted Cat's preference for this habitat type. Further detailed surveys and ecological studies on this species are needed to ensure its long-term conservation.

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Natural history notes on the highly threatened Pinto's Chachalaca *Ortalis remota* (Aves: Cracidae)

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The genus *Ortalis* (Cracidae) is endemic of the Americas and composed of 15 species (Billerman et al. 2020), generally found in pairs or small groups (Sigrist 2006). They present a varied diet including fruits, leaves, seeds, flowers, and arthropods (Billerman et al. 2020).

Pinto's Chachalaca (*Ortalis remota* Pinto, 1960; Aves: Galliformes: Cracidae) (Image 1) is one of the world's rarest cracids, nowadays restricted to fewer than 20 municipalities in eastern Brazil. It is threatened with extinction, listed nationally as "Critically Endangered" (Instituto Chico Mendes de Conservação da Biodiversidade 2018), mainly due to poaching and habitat loss (Rego 2009). It was described by Olivério Pinto as a subspecies of *Ortalis guttata* (Pinto 1960) based on a single specimen collected in Mato Grosso do Sul state and treated as a junior synonym of *Ortalis guttata squamata* by Vaurie (1965). However, recent reference works have considered it a valid taxon, either as a subspecies (e.g., Clements et al. 2019, Remsen et al. 2021) or full species (Silveira et al. 2017). Knowledge about the species' biology is limited, being the sole information available present in Silveira et al. (2017). Therefore, most of the natural history aspects of the species remain virtually unknown. The species is locally known as 'guarda-faca' (an onomatopoeic name which is a reference to the vocal duet of the species, according to locals from Guapiaçu: 'Guarda a faca vovô; tá na cara que eu vou'), 'jacuzinho', 'jacu-cigana', 'jacutinga', and 'jacupemba'.

Field campaigns to study the species were carried out from January to December 2018 (six to ten days each month, distributed in January, March, April, September, October, and December), during 43 days in 11 municipalities in the state of São Paulo (SP), Brazil (Image 2). Searches for the species were conducted in 28 municipalities using playbacks at previously defined points distributed in the visited forest fragments with potential occurrence of the species (riparian forests) every 200m. At each point, the species' calls were played for 5 min, and then 5 min of listening (adapted from Marion 1974; Marion et al. 1981; Schmitz-Ornés 1999).

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Image 1. Pinto's Chachalaca *Ortalis remota*.

For each individual seen, information regarding group size, food items, foraging behavior, and breeding biology were noted. Perches were classified by type (lianas, dry or green branches), inclination (vertical – 81° to 99°; horizontal – up to 10° inclination) and height in relation to the ground, also recording the portion of the branch in which the bird was perched (proximal, median or distal in relation to the trunk).

Group size. Individuals were found mostly in pairs (average individuals per group= 2.03 ± 0.67; min= 1; max= 5; n= 54).

Food items. On 14 March 2018, an individual was recorded feeding on the infructescence of *Cecropia pachystachya* Trec. (Urticaceae) in Nova Granada (SP). In 48 seconds of observation, 12 pecks were recorded in at least four infructescences. On 15 December 2018, an individual was seen feeding on *Psidium guajava* L. (Myrtaceae) fruits on the edge of the forest in Guaíra (SP). In addition, in 15 November 2017, individuals were observed feeding on the infructescence of *Cecropia pachystachya* in Guapiaçu (SP).

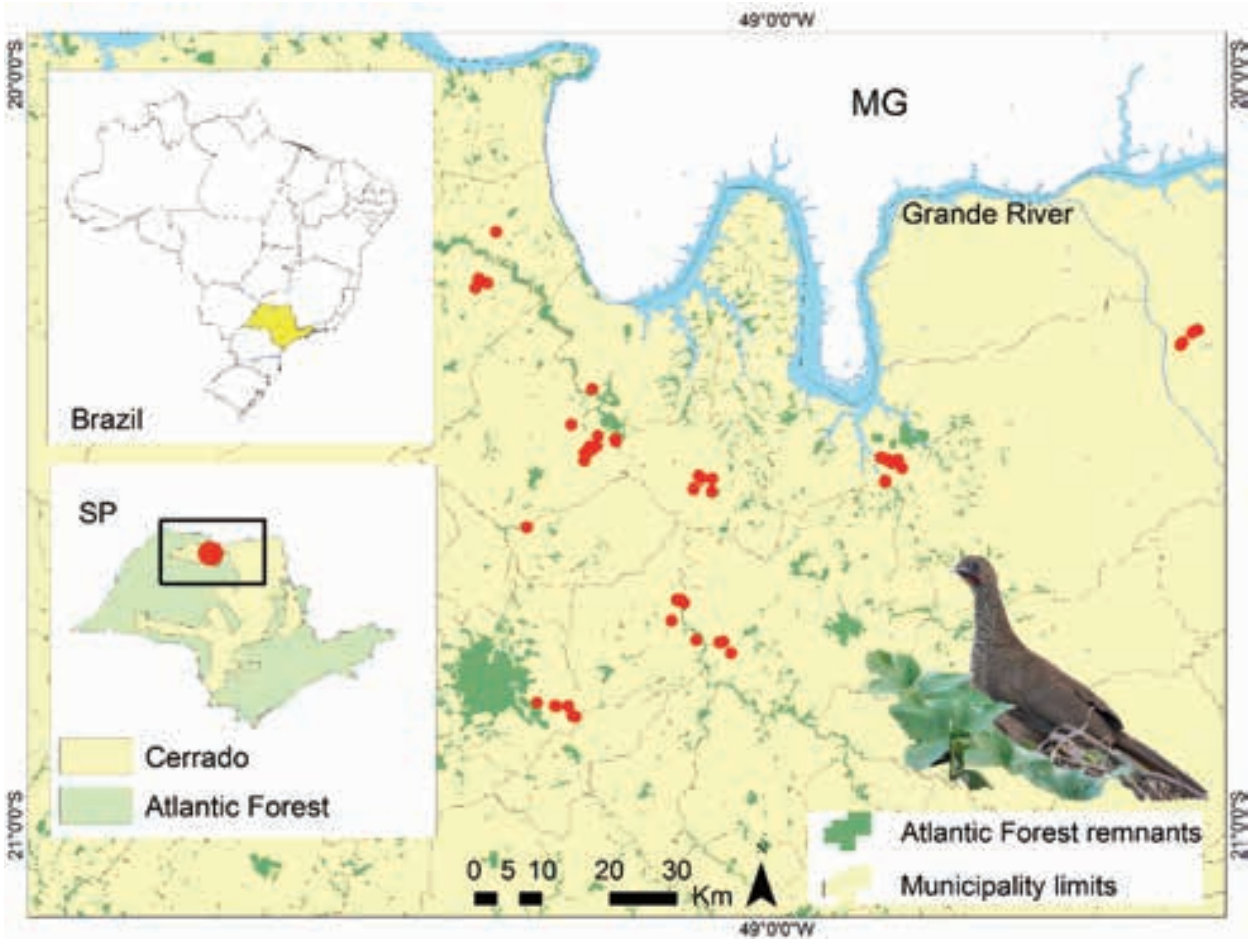

Image 2. Occurrence spots for *Ortalis remota* sampled in this study. Map elaborated by Paula Ribeiro Anunciação

Perches. 109 perching locations used by *O. remota* individuals were noted. Of this total, 96 (88.07%) were branches (88 inclined and 8 horizontal) and 13 (11.93%) were liana aggregations. The average inclination of the branches used as perches was 48.43 ± 20.19° (min= 10°; max= 80°) (n= 67). The majority of perches used (67.4%) were green branches, with 32.55% of the records in dry branches and one encounter on the ground (n= 86). The average height of the perches was 5.58 ± 2.6 m (min= 1 m; max= 12.5 m) (n= 109). In half of the observations (52%), the species was seen using the median portion of the perches, while the proximal portion was used 33 times (44%) and the distal portion three times (n= 75).

Reproductive biology. On 25 and 30 January 2018, four young individuals were found in two points (two in each) in the municipality of Guapiaçu (SP). In addition, Ciro Albano and Cristine Prates (pers. comm.) found a subadult following two adults on 16 May 2018, in Nova Granada (SP).

The fact that the species is found preferably in pairs, but also in small groups, agrees with what is described for most species of the genus *Ortalis* (Sigrist 2006). In addition, the two food items registered for the species are also part of the diet of other *Ortalis*. Five species of the genus have already been recorded feeding on *Cecropia* infructescence (Del Hoyo & Kirwan 2020a,b,c,d; Kirwan et al. 2020) and *O. cinereiceps* have already been observed feeding on *Psidium guajava* fruits (Del Hoyo & Kirwan 2020a).

Information on reproductive biology of *Ortalis* is scarce and highly scattered in literature and the data presented here are the first for *O. remota*. In Brazil, the breeding season varies significantly among species in the genus; however, most of the species of *Ortalis* have also been recorded breeding during the period that comprises the last and first months of the year (Billerman et al. 2020).

The data presented here about the perches utilized by the species are the first for the genus. This kind of information, along with the data about diet, group size and breeding biology, is utterly important for the design of ex situ conservation initiatives and breeding the species in captivity, which is one of the conservation strategies suggested by Silveira et al. (2017) for *O. remota*.

Despite the new information obtained in our study, many aspects of species' natural history remain poorly known and we encourage future work focusing on the biology of this highly threatened species.

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Black-bellied Coral Snake *Sinomicrurus nigriventer* (Wall, 1908) (Elapidae): an extended distribution in the western Himalaya, India

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The Indian Himalaya region (IHR) is bestowed with rich and endemic biodiversity (Pandit et al. 2007). It is broadly categorized into the western Himalaya, central Himalaya, and northeastern Himalaya (Nautiyal et al. 2005). The western Himalayan region has a unique topography, great variation in altitude and a broad range of vegetational and faunal diversity. The region serves as home for a variety of endemic and threatened fauna (Maikhuri 2018). Nested in the western Himalaya, the state of Uttarakhand possesses a distinct identity of its natural ecosystems, which supports a remarkable diversity of fauna, including at least 72 species of reptiles and amphibians (Vasudevan & Sondhi 2010). Interestingly, several studies on snake ecology have been conducted in the world, but a comprehensive understanding in terms of range distribution and population biology of many snakes is still deficient (Mullin & Seigel 2009).

Coral snakes are a large group of elapid snakes (Döring 2020), which are venomous but commonly less involved in envenomation (Richardson & Little 2012). Generally, elapid snakes are fossorial and show solitary behaviour (Döring 2020). Currently, 107 species of coral snakes belonging to five genera are recognized in the world, most of them (~76%) being found in the New World (Uetz et al. 2020). India is home to seven coral snake species (Whitaker & Captain 2004; Smith et al. 2012; Mirza et al. 2020), of these *Sinomicrurus macclellandi* (Reinhardt, 1844) was considered to have a wide distribution across the Himalaya, the northeastern hills, and adjoining countries, represented by at least five distinct 'colour forms' (Smith 1943).

The Black-bellied Coral Snake was initially described by British naturalist Col. Frank Wall as a variety of the Macclelland's Coral Snake *Sinomicrurus macclellandi*; however, in a recent study, Mirza et al. (2020) rediscovered this snake from Himachal Pradesh and compared it with existing museum specimens of *Sinomicrurus* spp. Based on morphological and molecular data, the authors concluded that *Sinomicrurus nigriventer* (earlier considered as a variety of *Sinomicrurus macclellandi*) deserves to be considered a distinct species.

Until now, *S. nigriventer* was only known to occur from Solan District (Kasauli and Nairani localities) of Himachal Pradesh, the western Himalaya (Wall 1908; Mirza et al. 2020). The current communication reports

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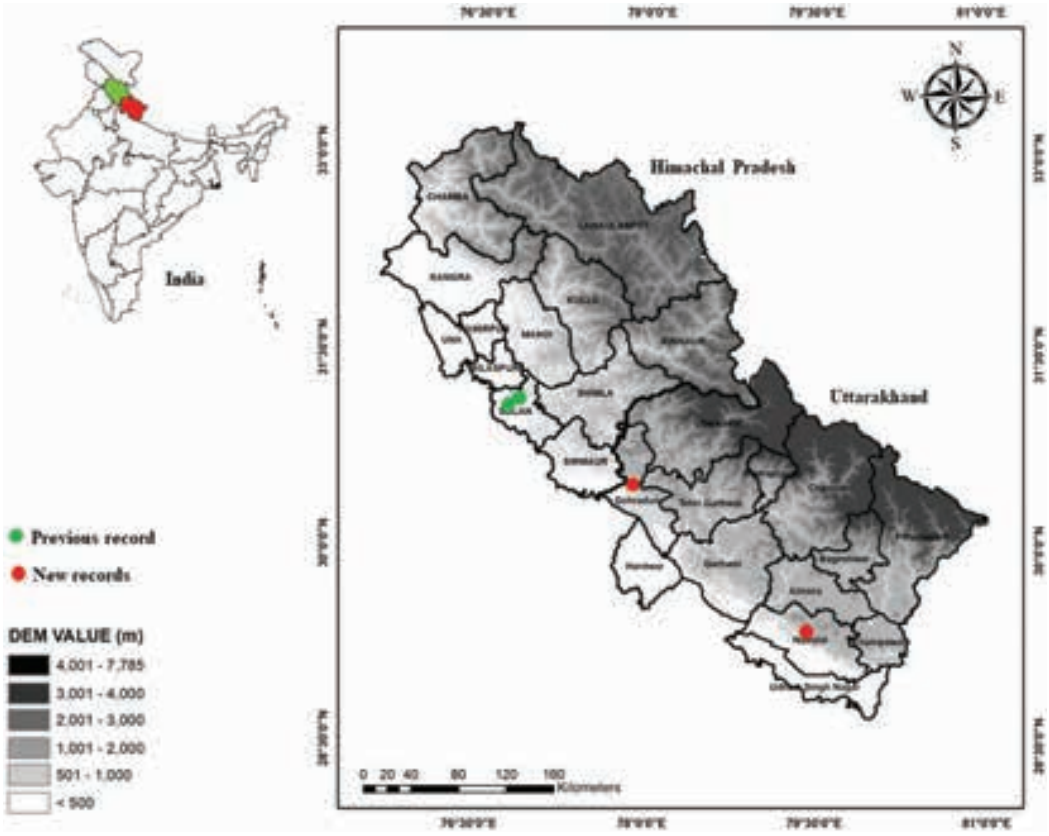

Figure 1. Distribution records of *Sinomicrurus nigriventer* in Himachal Pradesh and Uttarakhand in the western Himalaya.

for the first time, two confirmed distributional records of *S. nigriventer* from the adjoining Himalayan state of Uttarakhand (Figure 1), extending the geographic range of this newly proposed species further south and east along the western Himalaya.

During recent field explorations in the Kumaon and Garwhal regions of this largely mountainous state, the authors recorded a dead and a live specimen each. A detailed scrutiny of literature such as Reinhardt (1844), Wall (1908), Whitaker & Captain (2004), and Mirza et al. (2020) along with morphological characteristics revealed that both these individuals belong to the *Elapidae* family of *Sinomicrurus* genus, namely, *S. nigriventer*.

The first observation consists of a dead specimen of *S. nigriventer* found on 11 August 2019 from Nainital Forest Division at an elevation of 1,113 m (29.343^{0}N, 79.621^{0}E). The specimen was found upturned by the side of a small foot-bridge crossing a flowing stream (Image 1). Judging from its intact body, and the fact that no rigor mortis had set in, it appeared that this black-bellied coral snake had died recently, but the cause of death could not be ascertained although ants were seen feeding on it. The specimen was collected, fixed and preserved in 70% ethanol and deposited in the museum of the Wildlife Institute of India, Dehradun (WIIAD724). The total length of the snake recorded was 380 mm and tail length was 36 mm. The scale count of this specimen include dorsals 13:13:13, ventrals 231, sub-caudals 29 (paired), supralabials 7/7 and infralabials 7/7. The sighting location consisted of rocky slopes amidst riverside and major vegetation observed nearby were *Bauhinia vahlii, Debregeasia hypoleuca, Woodfordia fruticosa, Ricinus communis, Ageratina adenophora, Urtica dioica, Rubus ellipticus, Lantana camara*, and *Rumex nepalensis*.

The second, more recent observation consists of a live specimen of *S. nigriventer* encountered in the Bhadraj Block of Benog Wildlife Sanctuary (BWS) in Mussoorie Forest Division (Image 2). The snake was sighted on the way to Bhadraj temple (30.470^{0}N, 77.970^{0}E) during daylight (12:47 h) on 20 September 2020 at an elevation of 1,914 m. Information on the snake species was recorded, the snake was photographed and identified visually based on coloration and body pattern. BWS mainly constitutes of Ban oak *Quercus leucotrichophora* forest with dominant species such as *Rhododendron arboreum, Lyonia ovalifolia, Berberis* spp. and *Ageratina adenophora* and undulating terrain consisting of

Image 1. A dead individual of *Sinomicrurus nigriventer* found in Nainital Forest Division: A—ventral aspect | B—dorsal aspect. © Jignasu Dolia.

dense grassy slopes (Kumar et al. 2012). The area is characterized by small natural water catchments, although stagnant.

The first record of *S. nigriventer* is an important addition to the knowledge of medically important snakes of Uttarakhand. The recent specimen from Himachal Pradesh was reported from 870m elevation (Mirza et al. 2020) and the two specimens from Uttarakhand were found at 1,100m and 1,900m. Interestingly, both specimens were found during the monsoon period, which may suggest some seasonal activity pattern. Moreover, considering the limited distribution records of the Black-bellied Coral Snake from the western Himalaya, the current communication with a report on its occurrence in Nainital and Mussoorie forest divisions indicates that the cool sub-tropical and temperate forests (1,000–2,000 m) with dense grassy slopes are under-explored in terms of reptilian diversity. Further field investigations are required to determine the status of this venomous snake and to investigate if the species also occurs in similar habitats of the western Himalaya.

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Image 2. *Sinomicrurus nigriventer* recorded in Benog Wildlife Sanctuary, Uttarakhand. © Vartika Chaudhary.

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NOTE

First record of the Afghan Poplar Hawkmoth *Laothoe witti* Eitschberger et al., 1998 (Sphingidae: Smerinthinae) from India: a notable range extension for the genus

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Sphingidae moths can recognizably be identified with their robust streamlined body, rapid flight movement and narrow but powerful wings that are reminder of hawks, giving them the name 'hawk moths' (Messenger 1997). Family Sphingidae Latreille, 1802 comprises 1,602 species under 205 genera (Kitching et al. 2018). About 204 species are reported from India (Hampson 1892; Bell & Scott 1937; Roonwal et al. 1963; D' Abrera, 1986; van Nieukerken 2011; Avtar 2017; Geetha 2019; Pratheesh 2019). The genus *Laothoe* Fabricius, 1807 comprises five species distributed across the Palearctic region belonging to the tribe Smerinthini Grote & Robinson, 1865, under the subfamily Smerinthinae Grote & Robinson, 1865 (Zolotuhin 2018). The genus is characterized by its broad hindwing with strongly round anal angle; absence of frenulum and retinaculum in male and reduced in female; atrophied proboscis and spiny abdominal tergites (Fabricius 1807). The species *Laothoe philerema witti* Eitschberger, Danner & Surholt, 1998 was first described as a sub-species to *L. philerema* (Djakonov, 1923) with a single male holotype from Paghman, 30km north-west of Kabul, Afghanistan at an altitude of 2,100m. The species was recently re-instated based on DNA barcode divergence from *L. philerema* (Djakonov, 1923) confirming their species status as *Laothoe witti* Eitschberger, Danner & Surholt, 1998 raising it from the status of subspecies (Zolotuhin 2018). The wing span of this species ranges 120–140mm and is morphologically much similar to the smaller species *Laothoe philerema* (Djakonov, 1923), and paler species *Laothoe populi populi* (Linnaeus, 1758), the latter with distinctive prominent rust-red hindwing patch (Danner 1998).

The single adult specimen *Laothoe wiiti* (Image 2) was photographed and collected on 6 July 2020 in Tehsil Herman, district Shopian of Kashmir Division (Jammu & Kashmir), India, at an altitude of 1,596m (coordinates were 33.705^{0}N, 74.940^{0}E) (Image 2). The specimen was

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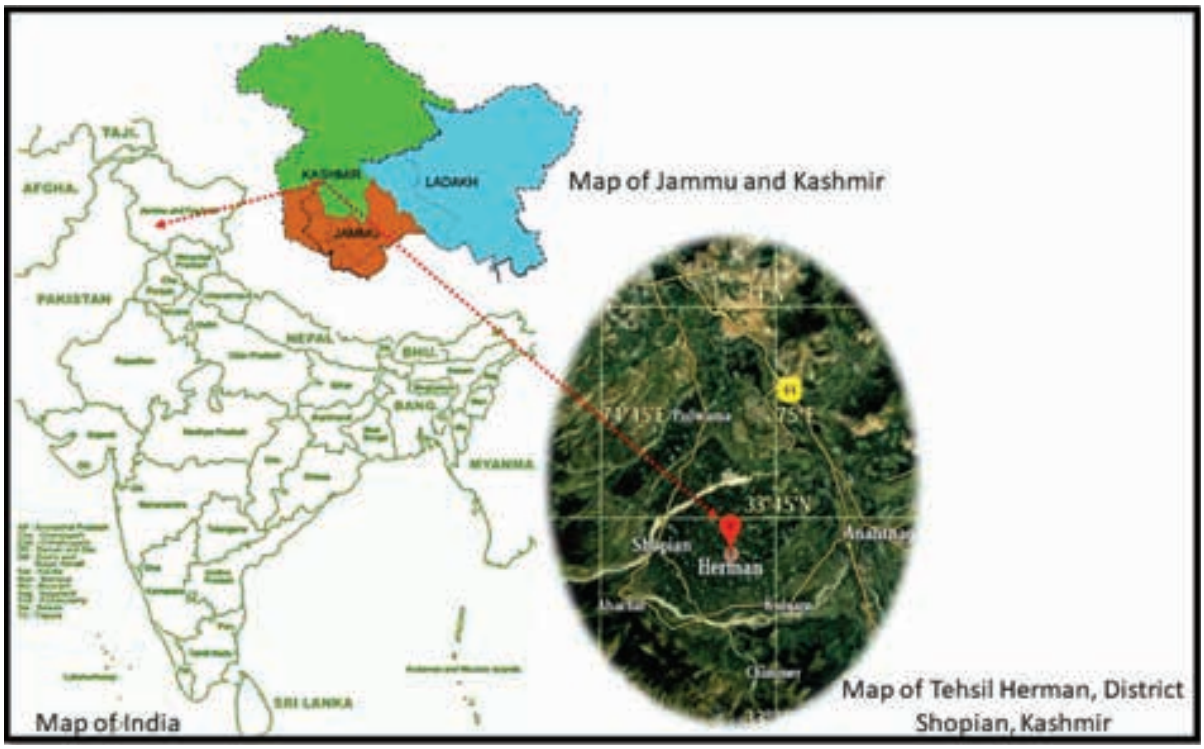

Image 1. Map of Shopian District showing location of collection site. (Source: Google maps).

Image 2. Specimen collected from Tehsil Herman, District Shopian of Kashmir.

collected by the first author while studying the diversity of insect fauna of Kashmir Valley, India and further taxonomic studies were conducted along with the other authors. Major tree species around the site were *Populus deltoides, Juglans regia, Robinia pseudoacacia, Ulmus* sp., *Salix* sp., and *Malus* sp. Temperature was recorded as 25ºC. The habitat mostly consists of agricultural lands with an annual precipitation of

Image 3. Stretched specimen showing wingspan. Mounted and stretched by Muzafar Riyaz

660mm and 13ºC average temperature (Wachkoo et al. 2018). The collected specimen is deposited in the museum of Division of Taxonomy and Biodiversity at the Entomology Research Institute, Loyola College Chennai, India with specimen voucher number ERIB-KMR-267. The wingspan of the individual was 12cm (Image 3). The identification of the specimen was done from the website http://tpittaway.tripod.com/sphinx/list.htm and http://sphingidae.myspecies.info/ by consultation with Dr. Ian Kitching. Notable range extension of the species within India was confirmed after checking the appropriate literature: Cotes & Swinhoe (1887), Bell & Scott (1937), Kitching & Cadiou (2000), Pittaway & Kitching (2000, 2018), Pittaway (2020), and Dar et al. (2020). This species was described and so far known only from eastern Afghanistan (Elberet 1969; Daniel 1971; http://tpittaway.tripod.com/sphinx/list.htm.)

The species shares similar morphology with *Laothoe philerema* (Djakonov, 1923) and can be distinguished by the following diagnostic features: forewing basal area paler; dark distinct antemedial band; pale medial band; waved post medial line with a dark spot at the middle; outer margin waved with prominent dark area between middle of outer margin towards apex; and paler hindwing with indistinct medial line darker towards costa; sub-marginal region greyish with dark patch near anal angle; outer margin with cilia whitish.

The genus *Laothoe* was recently reported with two species with two subspecies each namely *L. amurensis amurensis* (Staudinger, 1892), *L. amurensis sinica* (Rothschild & Jordan, 1903), *L. populi populeti* (Bienert, 1870), and *L. populi populi* (Linnaeus, 1758) were reported and described from China, North, and South Korea (Pittaway & Kitching 2000). The genus was reported in Europe recently with two species *L. amurensis* (Staudinger, 1892) and *L. populi* (Linnaeus, 1758) from Lithuania (Dapkus 2010). The presence of the genus was again reported with the species *L. populeti* Bienert, 1870 from Georgia (Didmanidze 2013). Two species of this genus, namely, *L. populi populeti* (Bienert, 1870) and *L. philerema* (Djakonov, 1923) were enlisted among the list of possible future addition to the Sphingidae fauna of Pakistan based on its presence in neighboring countries (Rafi et al. 2014). *Laothoe populi populeti* (Bienert, 1870) was again later reported from Iran and Turkey (Gahari & Naveen 2017; Seven & Cakir 2019).

Based on the previous observations with similar habitats the authors propose a tentative area of occurrence for this species to the entire area of Kashmir and northern parts of Jammu division of the state of Jammu & Kashmir in India. The authors expect the possibility of the species to occur in northern parts of Pakistan, the areas that connects the present location with the type locality – Kabul, Afghanistan. The IUCN Red List assessment of this species at the GeoCAT website based on the present identification, type locality and two other possible locations showed the species to be Vulnerable (VU) with extent of occurrence of 16,264.596km^2. This record is significant and important as it constitutes the first proven evidence of the occurrence of *Laothoe witti* Eitschberger, Danner & Surholt, 1998 in the Indian subcontinent making it a notable range extension for the genus *Laothoe* into the political boundary of India.

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NOTE

The tribe Cnodalonini (Coleoptera: Tenebrionidae: Stenochiinae) from Maharashtra with two new records

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The tenebrionids belonging to the tribe Cnodalonini Gistel, 1856 are small to very large (5–45 mm), of diverse shape and colour, apterous or winged. Antennae incrassate or weakly capitate, with stellate sensoria on apical 5 or 6 antennomere. Tarsi with ventral surface almost always flattened, bearing pads of yellowish, usually pilose setae; inner margins of tibiae frequently pilose, especially near apices; tarsomeres 3 and 4 subequal (Aalbu et al. 2002). As per the literature, only one species, *Bradymerus cucullatus* Fairmaire, 1897 from the tribe Cnodalonini was reported from Mumbai, Maharashtra State (Schawaller 2006). While studying the recent collections from Western Ghats survey of Maharashtra State, the two species identified as *Promethis brevicornis* (Westwood, 1842) and *Gebienocamaria girardi* Masumoto, 1993 belonging to the same tribe constitute two new records to Maharashtra. The number of species under Cnodalonini raised to three from Maharashtra. The specimens are photographed using a Nikon D300s DSLR camera and deposited in the national zoological collections of Western Regional Centre, Zoological Survey of India, Pune.

***Promethis brevicornis* (Westwood, 1842)**

Nyctobates brevieornis Westwood 1842: *Proc. zool. Soc. Lond*., 10: 119

Nyctobates brevicornis. Westwood, 1843: *Ann. Mag. nat. Hist.,* 11: 534.

Nyctobates brevieornis. Westwood, 1849: *Trans, zool. Soc. Lond*., 3: 226.

Setenis brevieornis. Waterhouse, 1876: *Ann. Mag. nat. Hist*., (4) 17: 289.

Nyctobates indosinicus Fairmaire, 1896, nec Fairmaire, 1893: *Annls Soc. ent. Belg*., 40: 27.

Systematic Position: as per Bouchard et al. 2005

Subfamily: Stenochiinae Kirby, 1837

Tribe: Cnodalonini Oken, 1843

Genus: *Promethis* Pascoe, 1869

Species: *brevicornis* (Westwood, 1842)

Diagnostic characters: *P. brevicornis* can easily be differentiated by the presence of hair fringe in the apical half of male protibia, the separate strial punctures of the elytra and the unmargined last ventrite as described by Fairmaire, 1896.

Body length: 26 mm; Maximum body width: 8.6 mm.

Material examined: Ent-1/3099, 25.i.2018, 07 ex.

Editor: Anonymity requested.

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

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Image 1. a—*Promethis brevicornis* (dorsal habitus) | b—Male protibia with hair fringe in the apical half | c—Unmargined last ventrite. © Authors.

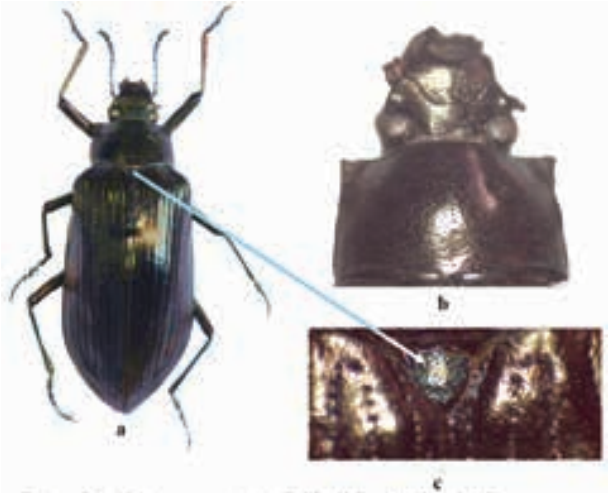

Image 2. a—*Gebienocamaria girardi* (dorsal habitus) | b—Head and pronotum | C—Scutellum (enlarged). © Authors.

Kalundhra, Sangli District, Maharashtra, under bark of the mango tree infested by unidentified fungus, coll. V.D. Hegde.

Distribution: INDIA: Karnataka, Maharashtra (Sangli District).

***Gebienocamaria girardi* Masumoto, 1993**

Gebienocamaria girardi Masumoto, 1993, *Jpn. J. Ent*., 61(2): 224.

Systematic Position: as per Bouchard et al. 2005

Subfamily: Stenochiinae Kirby, 1837

Tribe: Cnodalonini Oken, 1843

Genus: *Gebienocamaria* Masumoto, 1993

Species: *girardi* Masumoto, 1993

Diagnostic Characters: *G. girardi* can easily be differentiated by its pronotum which is rectangular, 1.4 times as wide as long, irregularly punctuate, with the corners projected and slightly reflexed; elytra a little more than 2.2 times as long as wide, 5.6 times the length and 1.7 times the width of pronotum as described by Masumoto (1993).

Body length: 27 mm; maximum body width: 9.6 mm.

Material examined: Ent-1/3100, 18.x.2016, 01 ex., Koyna Wildlife Sanctuary, Satara District, Maharashtra, (at light), coll. P.S. Bhatnagar.

Distribution: India: Tamil Nadu and Maharashtra (Satara District).

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Do predatory adult odonates estimate their adult prey odonates' body size and dispersal ability to proceed with a successful attack?

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The average body size and dispersal ability of a species significantly depends on its taxonomic order (Siemann et al. 1999). Indeed, there are significant body size and dispersal ability differences between predatory odonates and their typical prey items such as gnats, mayflies, flies, mosquitoes, and other small-sized flying insects. During one of my field visits in Sri Lanka in 2015, I observed an adult dragonfly (*Orthetrum sabina*) eating another species of dragonfly (*O. luzonicum*) (Image 1), and their average body sizes and dispersal abilities were similar. Similar observations were being circulated on Odonate-specialists' Facebook (FB) groups, suggesting that adult odonates feed on other species of odonates or even the same species (see Image 2). When predators prey upon members of the same taxonomic group, it is difficult to predict whether the predators still estimate the size and dispersal ability of their potential prey items to proceed with a successful attack (Woodward & Hildrew 2002). This, however, can be measured by using a robust statistical analysis and a precise dataset.

Even though adult odonates feed upon adult odonates, such records are uncommon. To build the dataset, I surveyed two private FB specialists' groups for such potential records. I manually checked every single post of the "*DragonflySouthAsia*" (https://www.facebook.com/groups/dragonflyindia) FB group between 2020 to 2016 and posts of the "*Dragonfly Interest Group of Sri Lanka*" (https://www.facebook.com/groups/256874097746055) FB group between 2020 to 2012. I also searched the "*Odonata of India*" (https://www.indianodonata.org/) website for more potential records. For most of those records, predator and prey species had been identified by experts within those groups. Prey odonates that could not be identified to species level due to predation were excluded from the final dataset. The records of mature predators preying upon juveniles were also excluded because that might result in some biases in the dataset as those individuals are immature. The final dataset included 67 records of adult predatory and prey odonate encounters from Sri Lanka (24) and India (43) — nine species of predators and 27 species of prey (see Table 1).

Morphometric trait measurement data related to body size and dispersal ability for each predator and prey odonate was extracted from the "Odonate Phenotypic Database" (OPD) at http://www.odonatephenotypicdatabase.org/ (Waller et al. 2019). When the data was not available in the OPD (only for eight species), the data was extracted from other published literature (see the Supplementary data for

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Table 1. Records of adult predator and prey odonate encounters from Sri Lanka (24) and India (43) from 2012 to 2020. Please see the supplementary data for additional information and references.

Record number	Country	Predator odonate species	Prey odonate species
Records of Anisoptera (dragonflies) preying upon Anisoptera (n= 40)			
1	Sri Lanka	*Orthetrum sabina*	*Neurothemis tullia*
2	Sri Lanka	*Orthetrum sabina*	*Neurothemis tullia*
3	Sri Lanka	*Orthetrum sabina*	*Diplacodes trivialis*
4	Sri Lanka	*Orthetrum sabina*	*Orthetrum pruinosum*
5	Sri Lanka	*Ictinogomphus rapax*	*Brachythemis contaminata*
6	Sri Lanka	*Orthetrum sabina*	*Brachythemis contaminata*
7	Sri Lanka	*Orthetrum sabina*	*Orthetrum luzonicum*
8	Sri Lanka	*Orthetrum sabina*	*Neurothemis tullia*
9	Sri Lanka	*Orthetrum sabina*	*Orthetrum luzonicum*
10	Sri Lanka	*Orthetrum sabina*	*Brachythemis contaminata*
11	Sri Lanka	*Orthetrum sabina*	*Orthetrum luzonicum*
12	Sri Lanka	*Orthetrum sabina*	*Orthetrum pruinosum*
13	India	*Orthetrum sabina*	*Neurothemis fulvia*
14	India	*Orthetrum sabina*	*Tetrathemis platyptera*
15	India	*Orthetrum sabina*	*Diplacodes trivialis*
16	India	*Orthetrum sabina*	*Potamarcha congener*
17	India	*Orthetrum sabina*	*Diplacodes trivialis*
18	India	*Orthetrum sabina*	*Orthetrum sabina*
19	India	*Orthetrum sabina*	*Diplacodes trivialis*
20	India	*Orthetrum sabina*	*Diplacodes trivialis*
21	India	*Orthetrum sabina*	*Orthetrum sabina*
22	India	*Orthetrum sabina*	*Orthetrum pruinosum*
23	India	*Rhodothemis rufa*	*Neurothemis tullia*
24	India	*Orthetrum sabina*	*Rhyothemis variegata*
25	India	*Orthetrum sabina*	*Orthetrum pruinosum*
26	India	*Orthetrum sabina*	*Potamarcha congener*
27	India	*Orthetrum sabina*	*Diplacodes trivialis*
28	India	*Orthetrum sabina*	*Orthetrum sabina*
29	India	*Orthetrum sabina*	*Orthetrum sabina*
30	India	*Orthetrum sabina*	*Crocothemis servilia*
31	India	*Orthetrum sabina*	*Trithemis aurora*
32	India	*Orthetrum sabina*	*Pantala flavescenes*
33	India	*Orthetrum sabina*	*Potamarcha congener*
34	India	*Orthetrum sabina*	*Diplacodes trivialis*
35	India	*Orthetrum sabina*	*Pantala flavescenes*
36	India	*Orthetrum sabina*	*Trithemis aurora*
37	India	*Orthetrum sabina*	*Tholymis tillarga*
38	India	*Acisoma panorpoides*	*Acisoma panorpoides*
39	India	*Orthetrum sabina*	*Orthetrum sabina*
40	India	*Orthetrum sabina*	*Paragomphus lineatus*
Records of Anisoptera (dragonflies) preying upon Zygoptera (damselflies) (n= 16)			
41	Sri Lanka	*Orthetrum sabina*	*Pseudagrion microcephalum*
42	Sri Lanka	*Acisoma panorpoides*	*Ceriagrion coromandelianum*
43	Sri Lanka	*Orthetrum sabina*	*Pseudagrion rubriceps*
44	Sri Lanka	*Orthetrum sabina*	*Pseudagrion microcephalum*
45	Sri Lanka	*Orthetrum sabina*	*Ceriagrion coromandelianum*
46	Sri Lanka	*Brachythemis contaminata*	*Pseudagrion rubriceps*
47	India	*Orthetrum sabina*	*Onychargia atrocyana*
48	India	*Orthetrum sabina*	*Lestes viridulus*
49	India	*Orthetrum sabina*	*Ischnura rubilio*
50	India	*Orthetrum sabina*	*Ischnura rubilio*
51	India	*Acisoma panorpoides*	*Ceriagrion coromandelianum*
52	India	*Acisoma panorpoides*	*Agriocnemis splendidissima*
53	India	*Brachythemis contaminata*	*Ischnura senegalensis*
54	India	*Brachythemis contaminata*	*Ischnura senegalensis*
55	India	*Orthetrum sabina*	*Ischnura senegalensis*
56	India	*Orthetrum sabina*	*Agriocnemis pygmaea*
Records of Zygoptera (damselflies) preying upon Zygoptera (n= 11)			
57	Sri Lanka	*Ceriagrion cerinorubellum*	*Ceriagrion coromandelianum*
58	Sri Lanka	*Ceriagrion coromandelianum*	*Agriocnemis pygmaea*
59	Sri Lanka	*Ceriagrion coromandelianum*	*Onychargia atrocyana*
60	Sri Lanka	*Ischnura senegalensis*	*Agriocnemis pygmaea*
61	Sri Lanka	*Ceriagrion coromandelianum*	*Pseudagrion microcephalum*
62	Sri Lanka	*Ischnura senegalensis*	*Agriocnemis pygmaea*
63	India	*Ceriagrion coromandelianum*	*Ceriagrion cerinorubellum*
64	India	*Ceriagrion coromandelianum*	*Ceriagrion cerinorubellum*
65	India	*Ischnura senegalensis*	*Agriocnemis pygmaea*
66	India	*Ceriagrion coromandelanium*	*Ischnura senegalensis*
67	India	*Ceriagrion coromandelanium*	*Agriocnemis pygmaea*

Image 1. A mature adult of *Orthetrum sabina* preying upon a mature adult of *O. luzonicum* at Sinharaja rain forest in Sri Lanka, 2015.

Image 2. A mature adult of *Orthetrum sabina* preying upon a mature adult of *O. sabina* at Tirupur, Tamil Nadu in India, 2018.

Table 2. Differences in body size (average body length in mm) and dispersal ability (hind-wing length in mm) between predator and prey odonates when both groups belong to Anisoptera (dragonflies) suborder (n= 40). SD indicates standard deviations, and L-95% and U-95% indicate 95% credible interval (lower and upper, respectively).

	Mean	SD	L-95%	U-95%
Body size of predator odonates	46.500	0.001	46.498	46.502
Body size of prey odonates	39.992	2.415	35.208	44.530
Body size differences between predator and prey odonates	6.507	2.415	6.492	6.522
Dispersal ability of predator odonates	30.500	0.0006	30.498	30.501
Dispersal ability of prey odonates	28.251	1.482	25.287	31.027
Dispersal ability differences between predator and prey odonates	2.248	1.482	2.239	2.257

Table 3. Differences in body size (average body length in mm) and dispersal ability (hind-wing length in mm) between predator and prey odonates when predators belong to Anisoptera (dragonflies) and prey belong to Zygoptera (damselflies) suborder (n= 16). SD indicates standard deviations, and L-95% and U-95% indicate 95% credible interval (lower and upper, respectively).

	Mean	SD	L-95%	U-95%
Body size of predator odonates	45.749	2.037	40.313	46.533
Body size of prey odonates	32.808	1.235	30.371	35.155
Body size differences between predator and prey odonates	12.941	2.252	12.926	12.955
Dispersal ability of predator odonates	30.499	0.003	30.494	30.505
Dispersal ability of prey odonates	18.624	0.871	16.797	20.221
Dispersal ability differences between predator and prey odonates	11.875	0.871	11.869	11.881

Table 4. Differences in body size (average body length in mm) and dispersal ability (hind-wing length in mm) between predator and prey odonates when both groups belong to Zygoptera (damselflies) suborder (n= 11). SD indicates standard deviations, and L-95% and U-95% indicate 95% credible interval (lower and upper, respectively).

	Mean	SD	L-95%	U-95%
Body size of predator odonates	32.984	0.938	31.117	34.820
Body size of prey odonates	28.387	2.477	23.564	33.450
Body size differences between predator and prey odonates	4.597	2.658	4.581	4.614
Dispersal ability of predator odonates	18.600	1.010	16.606	20.324
Dispersal ability of prey odonates	14.359	1.718	10.919	17.829
Dispersal ability differences between predator and prey odonates	4.241	2.009	4.228	4.253

references). The average body length of each predator and prey species considered as the body size and potential dispersal ability was measured with the hind-wing length (only males in mm) for each species (Moretti et al. 2017). To measure whether there is a significant difference in body size and dispersal ability between predatory and prey odonates, I performed a Bayesian t-test using the "BEST" package with flat priors (Kruschke & Meredith 2020). Due to available replicates and data distribution, the Bayesian t-test approach provides a more robust way of estimating posterior probabilities of group differences (Kruschke 2013; Kruschke & Meredith 2020). All the statistical analyses were performed in R version 4.0.3 (www.r-project.org/).

The final dataset showed three types of predation behaviors between the two suborders of Odonata, i.e., (i) Anisoptera (dragonflies) prey upon Anisoptera (60 %, n= 40), (ii) Anisoptera prey upon Zygoptera (damselflies) (24 % of n= 16), and (iii) Zygoptera prey upon Zygoptera (16 %, n= 11), but there was no record of Zygoptera preying upon Anisoptera. Therefore, three separate analyses were performed for each type of predation to estimate the body size and dispersal ability differences between adult predatory and prey odonates. Since each suborder was separately analyzed, the hind-wing length measurements were not scaled relative to body length.

The results of the analysis showed strong evidence that the predatory odonates performing the attack had larger body size and greater hind-wing length than their prey odonates across all three predation types (see Table 2–4). This indicates that predatory adult odonates may estimate the body size and dispersal ability of the adult prey odonates to execute a successful attack even when both groups belong to the same taxonomic group. *Orthetrum sabina* had the highest percentage with 70 % (n= 47) of attacks on both Anisoptera and Zygoptera species, including *O. sabina-O. sabina* attacks (Image 2). It is also important to note that the attacks of the predatory odonates were mostly on the head or thorax of their prey odonates.

Data accessibility: Supplementary data for this study is available at, https://github.com/Tharaka18/Predatory-adult-odonates-and-their-adult-prey-odonates

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NOTE

Rediscovery of *Ophiorrhiza incarnata* C.E.C. Fisch. (Rubiaceae) from the Western Ghats of India after a lapse of 83 years

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Ophiorrhiza L. a therapeutically important genus (Deb & Mondal 1997) belongs to the family Rubiaceae with 322 species in worldwide (POWO 2020). The distribution and diversity of the genus *Ophiorrhiza* is mainly recorded from tropical and subtropical regions of Asia, Australia, New Guinea, and the Pacific Islands (Darwin 1976; Chen & Taylor 2011; Duan et al. 2019). Among these, 52 taxa are found in India (Hareesh & Sabu 2018) and 21 taxa (including 12 endemics) are distributed in the evergreen forests of the Western Ghats (Deb & Mondal 1997; Sasidharan 2013; Nayar et al. 2014; Hareesh et al. 2015).

During the studies on endemic plants of Nilgiri Biosphere Reserve the authors collected an interesting species of *Ophiorrhiza* L. from the evergreen forest of Chandanathode, Wayanad District of Kerala. On the basis of critical studies based on pertinent literature (Fischer 1938, protologue; Deb & Mondal 1997) and type specimen at K (K000031234 image!), it is authenticated and confirmed to be *Ophiorrhiza incarnata* C.E.C.Fisch.

***Ophiorrhiza incarnata* C.E.C. Fisch.**
(Image 1)

Kew Bull. 1983(3): 124. 1938; Sebastine in Bull. Bot. Surv. India 4:223.1962; Deb & Mondal in Nayar & Sastry Red Data Ind. Pl. 1:337. 1987 & Bull. Bot. Surv. India 39:61.1997; Sasidharan, Bio. Doc. Kerala, Part 6. Flow. Plants: 227. 2004; Nayar et al. Flow. Pl. Kerala-A Hand Book 531. 2006.

Holotype: India: Kerala, Wayanad District, near Nadugani, vi.1937, *E. Barnes* 1559 (K000031234 image!)

Annual, erect herbs up to 30cm. high; branchlets terete, ascending, obscure brown-pubescent below the nodes; internodes 3–8 cm long with a vertical line of brown pubescence. Leaves simple, opposite, narrowly elliptic, 4–10 × 2–3.5 cm, base slightly in equilateral, margin slightly wavy, acuminate at apex, adaxial glabrous with dark green and abaxial pale green scabrid on the nerves; lateral nerves 8–10 pairs, arising at a wide angle from the midrib; petioles 5–15 mm long; stipules 3–8 mm long, early deciduous. Inflorescence terminal, capitate cymes; peduncles 2–4 cm long. Flowers actinomorphic, pentamerous, pinkish-white, heterostylous; bracteoles 5–8 mm long, ovate-lanceolate, subacute, slightly in equilateral, midrib distinct, pellucid-dotted; pedicels less than 1mm, very short. Calyx valvate, 1.5–2.5 mm long; tube 5–ribbed, 1.5mm long; lobes 5, broadly acicular, ca. 1mm long, glabrous. Corolla infundibuliform, 6–9

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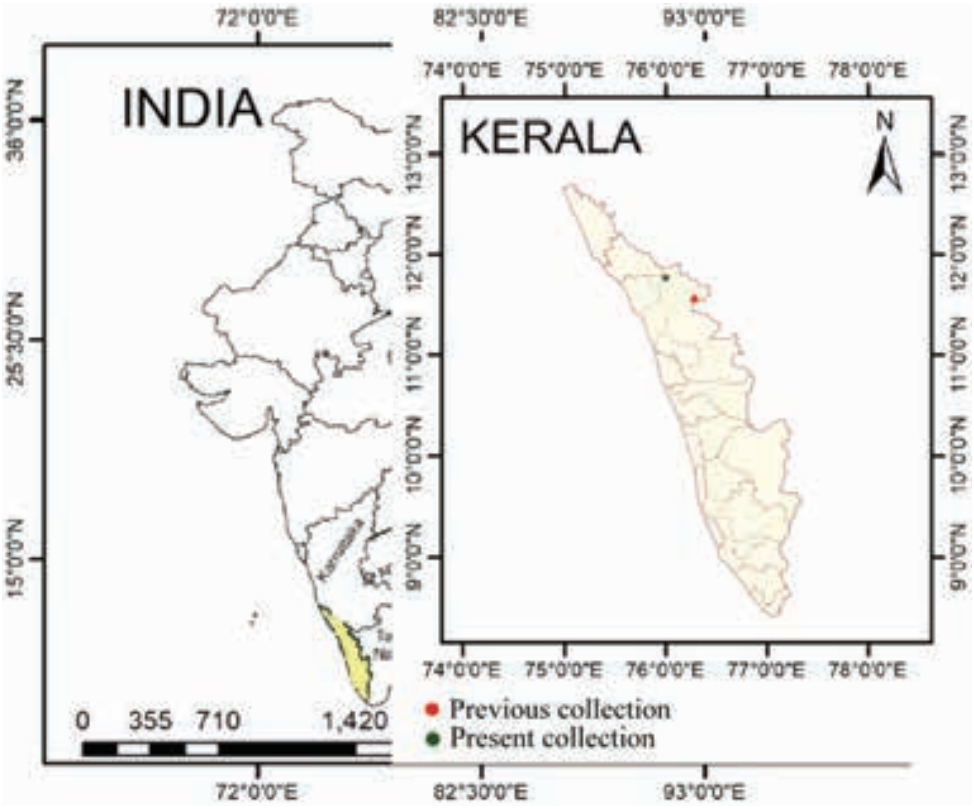

Figure 1. Distribution of *Ophiorrhiza incarnata* C.E.C. Fisch., in Western Ghats of India.

mm long, 5–lobed; tube 4.5–6.5 mm long, slender, very slightly widened at the mouth, glabrous; each lobe ca. 1.5mm long, broadly triangular, acute. Stamens 5, epipetalous, exserted, alternate to corolla lobes, attached to throat, inserted; filaments 2.5–3.5 mm long, slender; anthers ca. 2mm long, linear-oblong, 2–celled, basifixed. Ovary inferior, 0.8–1.3 mm long, obovoid; disk 0.5–0.6 mm high; style 0.8–2.5 mm long, slender; stigmas bilobed, linear, minutely puberulous. Fruit not seen (Image 1).

Flowering: April–June.

Distribution: India: Kerala (Wayanad).

Specimen examined: 144833 (MH!), 09.v.2019, India: Kerala, Wayanad District, Chandanathode, near stream side (11°50'55.7"N, 75°48'22.0"E, 754m), coll. P. Murugan & V. Ravichandran (Figure 1, Image 1).

Deb & Mondal (1997) reported that *Ophiorrhiza incarnata* C.E.C.Fisch. has been collected only once after the type based on the collection of C.E. Ridsdale 231 (MH00122489!) in 1976 from Mankulam presently at Idukki district of Kerala. After critical examination of this specimen with relevant literature, protologue and type specimen at K (K000174141 image!) it is found to be *Ophiorrhiza caudata* C.E.C. Fisch. Therefore, the present collection of *Ophiorrhiza incarnata* C.E.C.Fisch. forms the formal rediscovery after type collection by Barnes on June 1937 after a lapse of 83 years from the adjacent areas of the type locality. Despite several attempts by different workers in the type locality and adjacent areas it could not be collected after the type collection. The statement by Hareesh et al. (2015) about the introduction of *Ophiorrhiza incarnata* in Indian gardens seems doubtful, because Deb & Mondal (1997) clearly mentioned that it has been collected only once after the original discovery. It is a threatened species and deserves to be conserved in the wild and introduced into the garden.

The species is collected from swampy areas of Wayanad District of Kerala. No population is recorded after 1937 by Barnes. Present collection also located as single population of five individuals. Based on the study of literature, herbarium data and field observations *O. incarnata* is provisionally categorized as Critically Endangered (CR) based on highly restricted population numbers (<50 mature individuals) D (IUCN 2020).

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Image 1. *Ophiorrhiza incarnata* C.E.C. Fisch., dried specimen.

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RESPONSE

Comments on the "A checklist of mammals with historical records from Darjeeling-Sikkim Himalaya landscape, India"

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I would like to commend Naulak & Pradhan (2020) for their recent publication 'A checklist of the mammals of Darjeeling-Sikkim Himalaya landscape, India'. The region-specific taxonomic checklists are extremely useful for long-term conservation of biodiversity. I congratulate the authors for their attempt to bring out the publication on the "Checklist of mammals of Darjeeling-Sikkim Himalayas". However, in their checklist, Naulak & Pradhan (2020) include some doubtful species for which some additional information is solicited, without which their paper does not add any value and, instead, only adds more confusion to the mammalian literature of the Sikkim and Darjeeling region. Therefore, I provide the following comments:

Appendix I, # 122: Fishing Cat, *Prionailurus viverrinus*

The presence of Fishing Cat in Sikkim is doubtful. Naulak & Pradhan (2020) include this species based on two publications (Avasthe & Jha 1999; Srinivasulu & Srinivasulu 2012). However, Srinivasulu & Srinivasulu (2012) does not mention a fishing cat in Sikkim. Details in Avasthe & Jha (1999) could not be verified, but this being a non-peer-reviewed publication, one cannot accept this as the sole reference to validate the presence of a fishing cat in Sikkim.

In India, fishing cats have been recorded from Dudhwa Tiger Reserve and Soor Sarovar Bird Sanctuary in Uttar Pradesh (Mukherjee et al. 2012, 2016), Corbett Tiger Reserve in Uttarakhand, Sundarbans Tiger Reserve in West Bengal, Keoladeo Ghana National Park (Mukherjee et al. 2012) and Ranthambhore Tiger Reserve (Sadhu & Reddy 2013) in Rajasthan, Kaziranga Karbi Anglong Landscape (Mukherjee et al. 2016) and Manas Tiger Reserve (Mukherjee et al. 2016) in Assam, Valmiki Tiger Reserve (Mukherjee et al. 2016) in Bihar, Coringa Wildlife Sanctuary (Mukherjee et al. 2012; Malla & Sivakumar 2014) in Andhra Pradesh and Namdapha Tiger Reserve (Mukherjee et al. 2016) in Arunachal Pradesh. Outside the protected area network, records exist from Pilibhit Forest Division (Mukherjee et al. 2016) in Uttar Pradesh, in small wetland patches in West Bengal near Kolkata, and its suburbs like the Howrah and Hooghly districts (Adhya et al. 2011), in Medinipur and Nadia districts and the human-dominated north-eastern part of Chilika Lake and Tangi district (Mukherjee et al. 2016) in Odisha.

Thus, pertinent literature supporting the presence of a fishing cat in Sikkim is warranted if the record in Naulak & Pradhan (2020) is to be accepted.

Appendix I, # 139. Bengal Fox, *Vulpes bengalensis*

The presence of Bengal Fox from Darjeeling in Naulak & Pradhan (2020) is based on Agrawal et al. (1992), Saha et al. (1992) and Mallick (2012). Of these, Mallick (2012), and Saha et al. (1992), do not record this species from Darjeeling and Agrawal et al. (1992) report are based on a historical reference (Dash 1947). Moreover, Jhala (2016) does not record this species from Darjeeling.

Appendix I, # 143. Brown Bear, *Ursus arctos*

The presence of Brown Bear in Sikkim is based on

Citation: Nameer, P.O. (2021). Comments on the "A checklist of mammals with historical records from Darjeeling-Sikkim Himalaya landscape, India". *Journal of Threatened Taxa* 13(7): 18956–18958. https://doi.org/10.11609/jott.6658.13.7.18956-18958

Avasthe & Jha (1999) and Srinivasulu & Srinivasulu (2012). According to Srinivasulu & Srinivasulu (2012), Brown Bear is seen in the Himalayas in India, but there is no specific mention of the presence of Brown Bear in Sikkim. Avasthe & Jha (1999), on the other hand, being a non-peer-reviewed publication, cannot be accepted for establishing the occurrence of a species from a hitherto unreported region. Moreover, McLellan et al. (2017) does not report the species from Sikkim.

Appendix I, # 146. Eurasian Otter, *Lutra lutra*

The Eurasian Otter is included primarily based on either historical or 'grey literature, from both Darjeeling (Dalgilesh 1906; Wroughton 1916a, 1917; Agrawal et al. 1992), as well as Sikkim (Wroughton 1916b; Sanborn 1932; Avasthe & Jha 1999; Chattopadhyay et al. 2006). Chattopadhyay et al. (2006), a recent study, included *Lutra lutra* from Sikkim after Ghose & Biswas (1982), who did not provide any evidence. In this context, the presence of Eurasian Otter in this region cannot be accepted.

Appendix I, # 152. Himalayan Stoat or Ermine, *Mustela erminea*

The Ermine has been claimed to be occurring in Sikkim based on Vijayan et al. (2004) and Lepcha et al. (2017). However, Vijayan et al. (2004) make only a passing reference about the 'sighting' of an ermine from Sikkim, without any further details. Furthermore, neither any notes nor any pictures were provided; while Lepcha et al. (2017) could not be verified, but this being a non-peer-reviewed publication, more evidence are required before this species can be included in the Sikkim mammal list. Moreover, Ermine is known only from the Ladakh region in India to this date (Reid et al. 2016).

Appendix I, # 164. Red Muntjac, *Muntiacus vaginalis*

Though a taxonomic revision was proposed for *Muntiacus muntjac*, splitting the currently known species into three species has not been recognized (Mattioli 2011). Therefore, this species name should be changed to *Muntiacus muntjac.*

Appendix I, # 168. Takin, *Budorcas taxicolor*

A recent taxonomic revision of the Takin has led to two subspecies being elevated to distinct species, the Mishmi Takin *Budorcas taxicolor* and the Bhutan Takin *Budorcas whitei* (Groves & Leslie 2011), and it is the latter species that occurs in Sikkim.

Appendix I, # 172. Argali, *Ovis ammon*

The Altai Argali, *Ovis ammon*, is currently confined to Eastern Russia, Eastern Kazakhstan, Western Mongolia and North-West China (Groves & Leslie 2011), and the species present in India, including Sikkim, is the Tibetan Argali *Ovis hodgsoni*.

The comments and clarifications provided above need to be considered before the checklist of Naulak & Pradhan (2020) is used by biodiversity managers, scientists and inetrested public. It will also be beneficial if the authors correct the above errors and publish a corrigendum. This will help prevent misleading information to enter the published literature in future. Finally, there are also some errors in the spelling of scientific names (for e.g., *Mustela ermine*), which also need to be thoroughly checked, corrected and updated.

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