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Caption: Mudigere Skipper Frog *Euphlyctis* cf. *mudigere* from Coorg by Neelesh Dahanukar.

Building evidence for 20 years!

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When Sally Walker and I started conducting Red Listing workshops in India in 1995, we were constantly stumped by the facts that there were not many taxonomists and not many publications in peer-reviewed journals to refer to. Very well attended, the workshops of 4–5 days each usually brought out the best in experts compiling information for long durations of the day and into the night. Information, in some instances, was from the experts' field notes. In most cases, however, it was accumulated memory over the last few decades. This meant that the data were highly variable and awash with uncertainty.

We had many respected scientists tell us that the process really brought out the best observations from the fieldworks and that they never realized the data used in the assessments were important although they had observed them. Some confided that their intention to publish observations of species and habitats never materialized due to the lack of adequate support, lack of consistent journals within the country, and the lack of adequate grasp of the English language to communicate effectively as per the wishes of the expensive journals published from abroad. The combination of these with the unaffordability of accessing journals meant that many biologists in the region were devoid of literature to study, compare, and write about.

Zoos' Print was a popular magazine by then and due to its regularity (published on 21*st* of every month) efficiently set up by Sally since 1985, we started receiving technical articles of the kind needed for species assessments. By 1999, we were spending time in getting the manuscripts reviewed for facts, which then prompted Sally and me to think of a peer-reviewed section within *Zoos' Print*. So, we founded the *Zoos' Print Journal* and I was the chief editor. A small step to tackle the problems of publications, we embarked on a mission quite blind and, as with most things we do at Zoo Outreach Organization, quite broke. That was a commitment we made and so our journey began with a 12-page pull-out in April 1999.

Nine years on we were riding an evidence-building high within South Asia. Requests for global coverage became very strong. *Zoos' Print Journal* was being covered by Scopus and was available freely and widely. We took the next plunge—after a hiatus in 2008, we set up an independent publication with a title that did not confuse authors or readers as being restrictive—the *Journal of Threatened Taxa* was born. Known for its regularity, readers and authors now look forward to the 26th.

We've come a long way and have completed 20 years! This issue of *JoTT* marks the 21st year of publication and along with the milestone we continue to build evidence for conservation in more than 80 countries around the world on more than 60,000 species and ecosystems. This publication also marks the 250th issue.

On behalf of the co-founder Sally Walker and our small dedicated team in Wildlife Information Liaison Development (WILD) Society and Zoo Outreach Organization (Zooreach) of B. Ravichandran (Managing Editor), B.A. Daniel & Priyanka Iyer (Associate Editors), Vidya Mary George (Editorial Assistant), Latha Ravikumar (Web design and maintenance), Arul Jagadish (Typesetting), K. Geetha, S. Radhika, and Ravindran (Assistants), and other members of our editorial team from outside the organization, I thank you all for being a part of our growth and, most importantly, for helping in contributing to species and habitat conservation globally!

Sanjay Molur, PhD
Founder & Chief Editor, *JoTT*

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Effect of socio-ecological factors and parasite infection on body condition of Brown Mouse Lemur *Microcebus rufus* (Mammalia: Primates: Cheirogaleidae)

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Abstract: Various studies in ecology have shown the relationship between body condition and parasitic loads in nonhuman primates, however, little information is available regarding prosimians such as lemurs. In this study, the synergistic effect of parasite infection and socio-ecological factors on the body condition of *Microcebus rufus* in the family Cheirogaleidae was analyzed in Ranomafana National Park in southeastern Madagascar. This lemur species is characterized by its ability to adapt to different types of forest, and by seasonal fattening. Based on the factors considered, this species is, therefore, a good model for the study of body condition and ecology of infectious diseases in lemurs. Floatation and direct observation techniques were used for examination of parasite infection. Two indices considering body condition were analyzed: volume index (VI) and condition index (CI), the residual between the mass observed and the corrected mass. The generalized linear mixed model (GLMM) was used to model the synergistic effect of parasite infections and socio-ecological factors on variation in body condition, with the identity of individuals used as a random factor. We identified five species of helminths, one species of protist, and one species of lice which infected the 204 mouse lemurs captured. There was a sexual difference for all measures of the parasite infection. The more parasite species an individual was infected with, the smaller was its body size according to the Volume Index that reflects deposits of subcutaneous fat. Individuals with more positive Condition Index values, particularly females, excreted more parasite eggs or oocyst in their faecal matter. The results suggest that an individual's body condition constitutes an indicator of risk of parasite infection and transmission.

Keywords: Condition index, infectious disease, Ranomafana National Park, southeastern Madagascar, volume index.

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

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INTRODUCTION

The knowledge of body condition of an animal is of considerable importance in ecological studies and in the detection of diseases (Coop & Holmes 1996; Alzaga et al. 2008; Munyeme et al. 2010), as a tool for wildlife management (Ezenwa et al. 2010), and as an important indicator for numerous infectious diseases that affect the fitness of an individual (Sheldon & Verhulst 1996). Animals in a poor condition are often loaded with more parasites than individuals in a better condition (Wilford et al. 1986; Chapman et al. 2006; Tompkins et al. 2011). In addition, they are particularly susceptible to parasitic infections, leading to a "vicious cycle" of continuous parasitic infections and deteriorating health (Beldomenico & Begon 2010).

Thus, parasites play a key role in tropical ecosystems and affect not only the ecology and the evolution of intra- and interspecific interactions (Kappeler & Van Schaik 2002; Kappeler et al. 2015), but also the regulations of the host species health (Esch & Fernandez 1993; Hudson et al. 1998; Hochachka & Dhondt 2000; Hudson et al. 2002; Loudon et al. 2006). Understanding the functioning of parasite populations and the condition of the hosts within ecosystems is crucial, both in terms of parasite and host behavior (Schwitzer et al. 2010) and with regard to the epidemiological risk to host health (Silk 1986; Sanchez-Villagra et al. 1998; Gillespie & Chapman 2008).

Although studies on body condition, feeding, parasites, and disease have been conducted on monkeys in captivity and in the wild (Chapman et al. 2006; Altizer et al. 2007), little information has been collected about body condition indices, risk factors for parasite infection, and the relationship between body condition and parasites in prosimian primates such as lemurs, particularly in nocturnal species (Rafalinirina et al. 2015). We chose to study a member of the family Cheirogaleidae (Brown Mouse Lemur *Microcebus rufus* Vulnerable) in Ranomafana National Park (RNP) in southeastern Madagascar (Image 1). This species is widespread and easily adaptable to secondary forests and degraded vegetation, thus it is possible for it to encounter different types of parasites. Additionally, it is characterized by seasonal fattening (though not for all individuals at this site) in preparation for the dry season followed by torpor (Atsalis 1999). Therefore, it is a good model to show the relation between body condition and parasite infection ecology of lemurs, according to socio-ecological factors (sex, year of study, site, and period of capture) present in a natural environment for conservation management. Indeed, the purpose of this study was to examine indices of body condition, parasitic infection, and the synergistic effect of socio-ecological factors and parasitic infection on body condition. The analysis of morpho-physiological characters and the examination of feces seem to be the most effective methods for achieving this objective.

Image 1. Brown Mouse Lemur *Microcebus rufus*

MATERIALS AND METHODS

Study Site

Ranomafana National Park (RNP) is located in southeastern Madagascar. It is 65km northeast of the city of Fianarantsoa and adjacent to the village of Ranomafana, midway along the National Road 25 connecting Fianarantsoa and Mananjary. It lies in the geographical position Latitude 47.333^{0}E and Longitude 21.266^{0}S with an altitude between 400m and 1417m (Wright 1992; Wright & Andriamihaja 2002). The Park covers an area of 41,613ha, within which we collected samples at three sites: the Ranofady circuit (47.420^{0}E, 21.260^{0}S); the campsite of the Valbio Center (47.419^{0}E, 21.253^{0}S); and the Talatakely tourist site (47.421^{0}E, 21.262^{0}S) (Wright et al. 2009) (Fig. 1).

Data collection

Microcebus rufus were captured five days per week using Sherman traps (XLR, Sherman Trap Inc., Florida, USA 22.2 x 6.6 x 6.6 cm) from August to December in 2012, 2013 and 2015:

Data were collected according to three selected periods: Period 1 (before mating: mid-August to the beginning of October), Period 2 (mating, defined by the dates between which first and last vaginal opening were observed, most of October), and Period 3 (after mating: from November to December).

We measured the following morphometric points

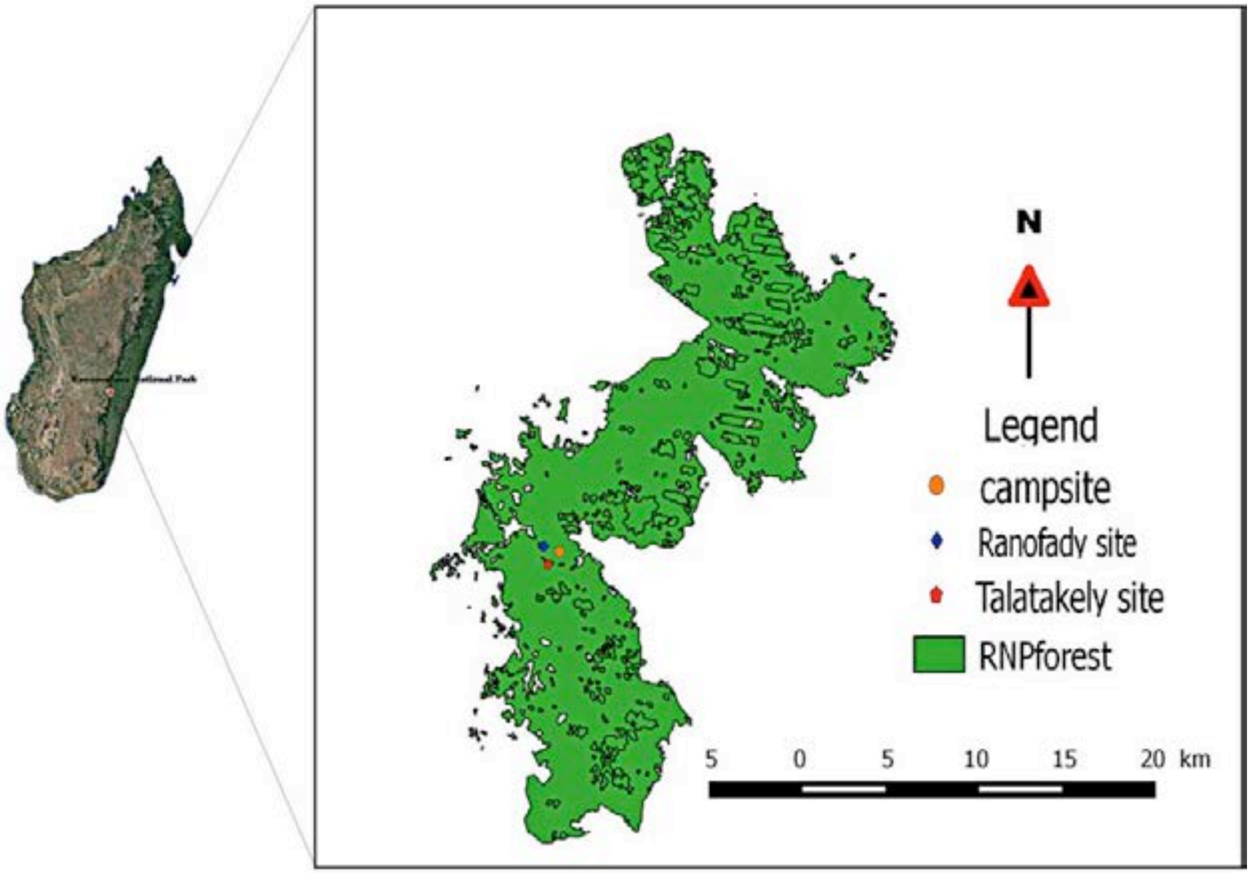

Figure 1. Study area in Ranomafana National Park, southeastern Madagascar.

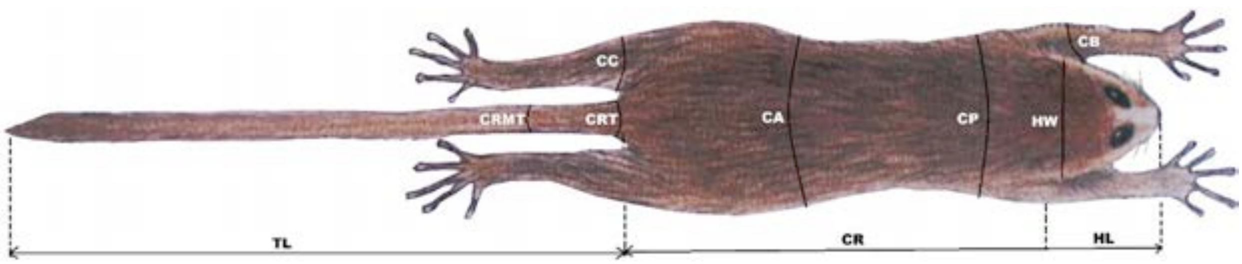

Figure 2. Different morphometric points for *Microcebus rufus.*

at the circumference of: the base of the tail (CRT), the midpoint of the tail (CRMT), the chest (CP), the hip (CA), the biceps (CB), and the thigh (CC). We also, measured body mass (M), body length (BL, from the prominent occipital point to the base of the tail), the length of the tail (TL, from the base to the tail tip), the length of the head (HL, from the tip of the nose to the prominent occipital point), and the width of the head (HW, between the two temples) (Fig. 2).

We also calculated the approximate body volume by the formula established by (Labocha et al. 2014):

$$BV = 1 / 3\pi TBL(RC^2 + RC^* RH + RH^2)$$

BV: Body volume, TBL: Total Body Length (BL+TL+HL), RC: Ray of Chest, RH: Ray of Hip.

Individual fecal samples were collected inside the traps, in bags, or directly from the anus for analysis. Because with the small lemurs only feces less than 1g were recovered: ~0.3g of fecal matter was recovered from each individual (Kessler et al. 2015; Radespiel et al. 2015).

Analysis

(a) Fecal analysis

We analyzed fecal material without preservatives in the ValBio Center lab, following Gillespie's method

(2006). The modified floatation technique using Sheather's solution (454g table sugar, 355ml tap water, 6ml formaldehyde) (Dryden et al. 2005) allows for the counting of eggs, larvae, and parasite oocysts in McMaster slides (Weber UK International Scientific).

Three parameters were used to determine parasite infestation: parasite species richness (PSR) (number of species or types of parasites encountered in a host individual. The index reflects the polyparasitism of individual hosts); parasite prevalence (number of host individuals infested by a particular parasite divided by the number of hosts examined multiplied by 100); parasite abundance (number of parasite eggs or parasitic elements per gram of feces).

For confirmation, we used the key determination of nematodes eggs, tapeworms and protozoan cysts published by Raharivololona (2009), as well as the genetic analysis methodology done by Aivelo (2015).

(b) Research on Ectoparasites

Microcebus rufus from Ranomafana exhibit ectoparasites such as lice (*Lemurpediculus verruculosus*) (Durden et al. 2010). In this study, the presence of this ectoparasite was verified for each individual, most often encountered at the abdomen, genitals, ear, and eyebrow. Ectoparasites were counted and quantified according to abundance on the body (Rafalinirina et al. 2015).

(c) Body Condition Estimation

For *Microcebus rufus*, we determined body condition based on the non-destructive estimation method (Green 2001; Stevenson & Woods 2006). We used body mass, the size, or the appearance of energy reserves. According to the recommendation of Peig & Green (2009), the body condition of an individual is estimated from the scaled mass index (SMi):

$$SMi = Mi\left[\frac{TBLo}{TBLi}\right]^{bSMA}$$

with $bSMA = b/r$ where Mi and TBLi are the body mass and total body length of individual i respectively; bSMA is the scaling exponent estimated by the standardized major axis regression of M on TBL, and TBLo is the arithmetic mean of TBL for our study population.

The difference or residual (CI) between the observed body mass M and the mass corrected for the individual size SMi gives the loss or mass gain in this research. Therefore, the value of the negative CI reflects a loss of mass reflecting poor animal health, while its positive value indicates a gain of mass reflecting good health.

Microcebus is one of the only primates that stores fats in the caudal section, used as a source of energy. We calculated the Volume index (VI) resulting from the principal component analysis of circumference measurements (CRT, CRMT, CB, CC), including body volume (BV) (Appendix 1).

(d) Statistical Analysis

The capture-mark-recapture technique was utilized, and thus each individual of *Microcebus rufus* contributes a maximum of data points in each period for all the data. Therefore, if there are multiple data points available for an individual during a period, then the average of the parameters studied will be used. For data recording and manipulation, we used Excel, after which the arranged data was transferred to SPSS version 22.0 (SPSS Inc., an IBM Company product, Chicago Illinois) for description, analysis and statistical modeling.

A principal component analysis was used to condense information from collinear variables (Zuur et al. 2010). In addition, GLMM was used to understand and analyze the effect of parasite infection measures and socio-ecological factors on the change in body condition index, with normal distribution and identity link function. In the analysis, the identity of the individuals (ID) was used as a random effect. All statistical analyses were two tailed and $P < 0.05$ was considered statistically significant.

RESULTS

The parasites of *Microcebus rufus*

In the 204 lemur individuals captured, five helminths and one protozoan species of gastrointestinal parasites were identified. The helminthofauna includes four nematodes, three Strongylidae species (*Strongyloides* sp., *Trichuris* sp., *Trichostrongylus* sp.), a species of the order Ascaridida (*Ascaris* sp.), and one cestode belonging to the genus Hymenolepis (Image 2). The protozoan species identified was coccidia.

In addition to the aforementioned gastrointestinal parasites, one species of lice (ectoparasites) of the order Phthiraptera, *Lemurpediculus verruculosus,* was found (Image 3).

(a) Parasite prevalence of *Microcebus rufus*: Among the parasite species inventoried, the prevalence of *Strongyloides* sp., *Hymenolepis* sp., *Lemurpediculus verruculosus,* and Coccidia were the most dominant (Fig. 3), which is to say that *Microcebus rufus* in Ranomafana National Park are most infested by these three gastrointestinal parasite species and this species of lice.

For the overall prevalence of these parasites in the

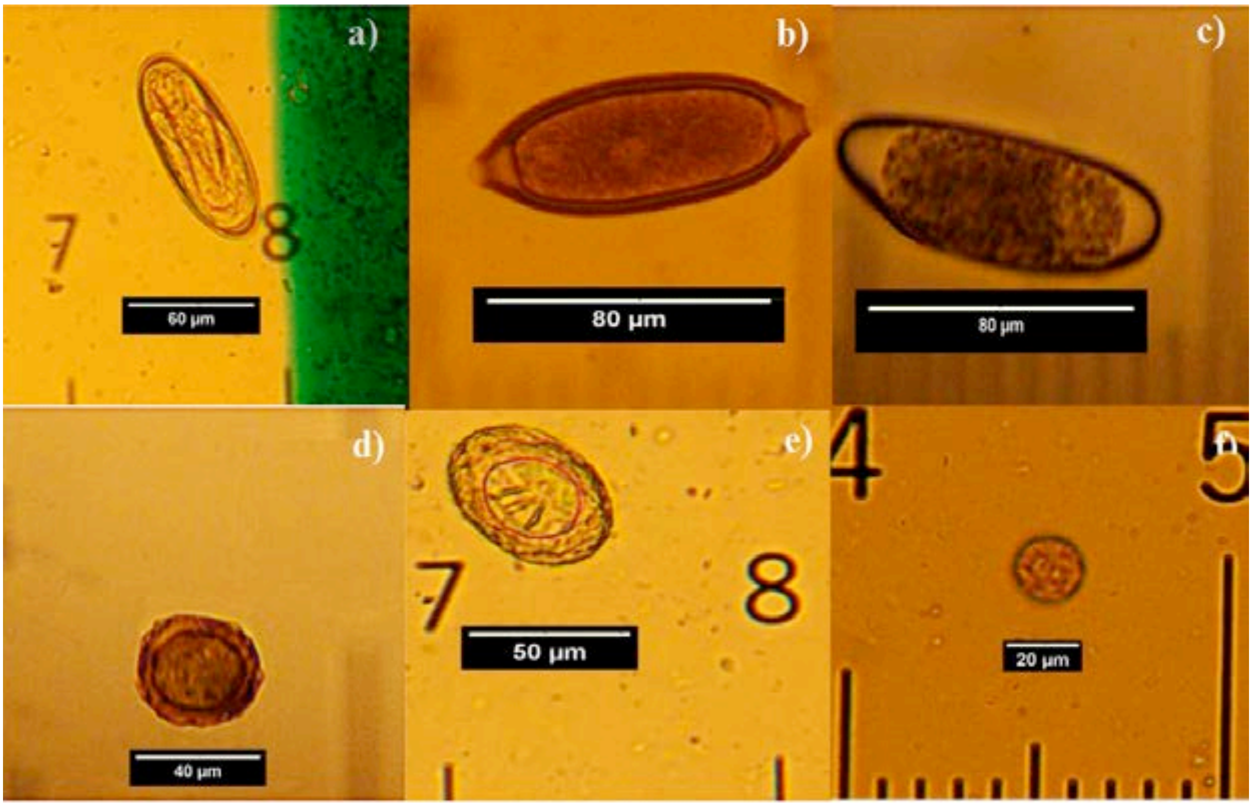

Image 2. Gastrointestinal parasite found in feces of *Microcebus rufus*: (a) *Strongyloides* sp. | (b) *Trichuris* sp. | (c) *Trichostrongylus* sp. | (d) *Ascaris* sp. | (e) *Hymenolepis* sp. | (f) a non-identified oocyst of Coccidia.

Image 3. An ectoparasite *Lemurpediculus verruculosus* found in *Microcebus rufus.*

Park, there is a significant infestation of *Strongyloides* sp.: 43.69% of the captured individuals were infested (173 individuals out of 204) by this parasite, 16.67% (66 out of 204 individuals) were infested by the *Hymenolepis* sp., and 23.99% (95 out of 204 individuals) and 11.87% (47 out of 204) were infested with ectoparasite and Coccidia.

The nematode is most widespread parasite, followed by ectoparasites, cestode and protozoans in the *Microcebus rufus* of Ranomafana National Park,. Therefore, there is a significant risk of epidemic in the area.

(b) Parasite abundance and species richness of *Microcebus rufus*: Males had the highest parasite abundance number for all parasites (Appendix 2) which presents a risk in the propagation of these parasites. We also observed that the group in Ranofady excreted many *Strongyloides* sp. eggs in their fecal matter, the individuals in Talatakely excreted the most cestode eggs and the lice were there in abundance. Therefore, there are significant incidences of these parasites in these sites. Moreover, the result showed an abundance of parasites during the mating period, which means a high risk of infestation. In addition, there was an increase in the number of nematode eggs in the fecal matter of *Microcebus rufus* during the study years, thus a proliferation of infections. However, a regression of the number of lice that infect the body has been observed. The cestodes were not present in the year 2013 but reappeared in 2015.

For the specific richness of parasites, this index reflects polyparasitism in a host individual. In this study, we observed that 63.23% of *Microcebus rufus* present a polyparasitism – that is to say that 129 of the 204 captured are infected by at least two species of parasites

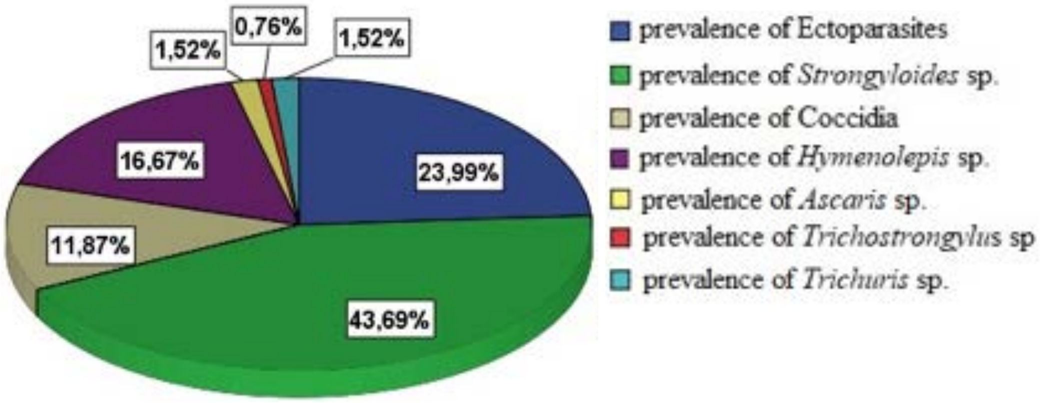

Figure 3. Prevalence of parasite infection in *Microcebus rufus* at RNP.

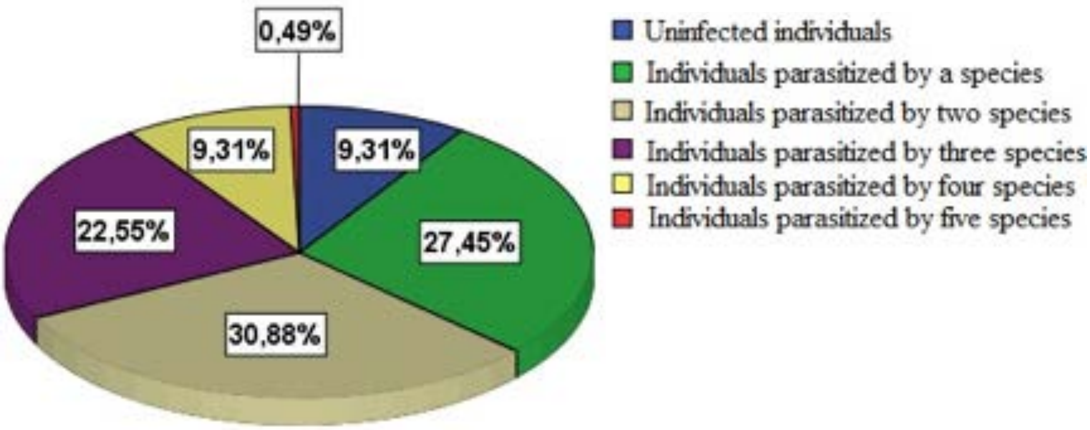

Figure 4. Frequency diagram of the parasites species richness of *Microcebus rufus* at the RNP.

(Fig. 4). Specifically, 63 individuals harbored two distinct parasite species (30.88%), 46 host three (22.5%), and one hosts five species (0.49%).

We found a positive linear correlation between indices of parasitic infections. In order to synthesize all this information on the correlations between parasite infection indices in *Microcebus rufus*, a principal component analysis for quantitative variables (parasite abundance) was carried out (Appendix 3). This allows condensing information on these variables according to synthetic factors (or components), analyzing and determining risk factors in statistical modeling.

Effects of socio-ecological factors and measures of parasitic infections on the body condition of *Microcebus rufus*

(a) Effects of socio-ecological factors and measures of parasitic infections on the variation of the volume index (VI): There was a significant effect of the species richness on the VI (F = 6.53, p = 0.012) (Table 1). The PSR had a negative impact on the body condition index (b = -0.18, t = -2.56, p = 0.012) (Appendix 4). This means that for an infestation of an additional parasite species, the Volume Index for *Microcebus rufus* decreases significantly by 0.18.

The interaction between year of study and sex had a significant impact on the variation of the VI (F = 7.17, p = 0.001), as well as for the combinatorial effect of sex and period (F = 5.81, p = 0.004). With the predictors continuously fixed at the following values: PSR = 2, parasite abundance = 0.02, it is estimated that females during the year 2013 have more than 1.26 of VI compared to that of the males of the same year and the individuals of the year 2015. That is to say that during that year, females were much larger than males. In addition, the female individuals before (b = -1.05, t = -2.95, p = 0.004) and during the mating period (b = -0.92, t = -2.86, p = 0.005) (Appendix 4) had low volume indices (less bulky) compared to those after the mating period and males during all periods.

(b) Effects of socio-ecological factors and measures of parasitic infections on the change in body condition

Table 1. General linear mixed model (GLMM) of variation VI in *Microcebus rufus*.

Dependent variable	Predictors	*F*	df	*p*
Volume Index	Year of study	0.96	2	0.387
	Sex	0.94	1	0.334
	Period	1.68	2	0.190
	Site	1.23	2	0.295
	PSR	6.53	1	**0.012**
	Abundance Parasites Factor	0.00	1	0.971
	Year of study * sex	7.17	2	**0.001**
	Year of study * period	0.11	3	0.954
	Year of study * site	0.01	1	0.915
	Sex * period	5.81	2	**0.004**

Distribution of probability: Normal, identity link function | df - degree of freedom | PSR - Parasites Specific Richness.

Table 2. General linear mixed model (GLMM) of CI variation in *Microcebus rufus*.

Dependent variable	Predictors	*F*	df	*p*
CI	Year of study	7.74	2	**0.001**
	Sex	0.07	1	0.796
	Period	0.79	2	0.457
	Site	5.07	2	**0.007**
	PSR	0.05	1	0.822
	Factor abundance of parasite	4.15	1	**0.043**
	Year of study * sex	17.42	2	**0.000**
	Year of study * period	0.20	3	0.899
	Year of study * site	2.22	1	0.138
	Sex * period	0.43	2	0.650

Distribution of probability: Normal, identity link function | df - degree of freedom | PSR - Parasites Specific Richness.

index (CI): A significant variation in body condition was observed for the year of study (F = 7.74, p = 0.001). The populations of *Microcebus rufus* during the years 2012 and 2013 lost respectively 3.75g (t = -3.30, p = 0.001) and 4.39g (t = -3.40, p = 0.001) of body condition compared to those of 2015. A significant variation was also observed according to site (F = 5.07, p = 0.007), as well as for the combinatorial effect of year of study and sex (F = 17.42, p = 0.000). The group of *Microcebus* in the Ranofady site lost a significant 6.45g (t = -5.44, p = 0.000) of the body condition (CI) compared to those of the Talatakely site. Moreover, it is estimated that female *Microcebus rufus* individuals from 2013 and 2015 are in more optimal condition compared to males of the same year (Appendix 5).

Lastly, we observed significant effect of the parasite infection measure “parasite abundance” on the change in body condition (F = 4.15, p = 0.043) (Table 3). The marginal impact of this parasite infection measure on CI was positive (b = 0.60, t=2.04, p=0.043). This means that if the body condition of the infected *Microcebus* increases by 0.60g, then it will have a secretion of an egg or oocyst number per gram of feces.

DISCUSSION

Parasitic infections are a critical part of the study of conservation biology (May 1988). Parasites, by their very nature, rely on host resources and may affect host survival and reproduction indirectly by reducing the body condition of the host (Coop & Holmes 1996; Neuhaus 2003; Gillespie & Chapman 2005). Individuals in poor condition are unable to resist parasitic infections because of the energy expenditure required for immune defense (Martin et al. 2003). To our knowledge, there are still only a few studies on the effects of gastrointestinal parasites on body condition and socio-ecological factors favoring lemurs. Our results on the effect of socio-ecological factors and parasite specific richness on the VI support these findings. It has been observed that the fixed effect of polyparasitism has a negative impact on the VI, as well as the interaction of the factors favoring sex and year, sex, and period respectively. *Microcebus rufus* individuals infected with several species of parasites are less bulky and this is more noticeable in females before and during the mating season. This also demonstrates that the multiple infections could have a direct consequence on the host by depleting fat reserves, since the VI reflects the deposition of subcutaneous fat. Our model suggests that *Microcebus rufus* females infected by multiple parasite species have a lower VI. It has been found that either these low VI individuals have an inability to overcome multiple infections, or that the harmful effects of multiple infections lead to poor condition (Rodriguez-Zaragoza 1994); however, the worsening body condition could have a direct effect on survival and reproduction (Coop & Holmes 1996; Murray et al. 1998), with females being especially affected. Thus, it seems that there is a threat to the continued viability of the population of *Microcebus rufus* in Ranomafana National Park, which could result in a decrease of the number of *Microcebus* captures in this park. In addition, analysis of the effects of socio-ecological factors and parasitic infection measures on CI gives us valuable information. The fixed effect of parasitic abundance on CI (difference or residual of SMi on M), suggests that the more a *Microcebus* individual gains weight (positive CI), the greater the number of eggs or oocysts in the feces. For females in particular, positive CI was associated with higher numbers of eggs per gram of feces (EPG). This suggests that it is the females that are the reservoir and responsible for the high incidences of gastrointestinal parasite in the study site. This same result showed us that a healthy host promotes the parasite's development cycle, meaning there is host tolerance in parasite reproduction. This demonstrates that parasitic infections do not always lead to an immediate effect on the host (Bize et al. 2008; Seppälä et al. 2008). Rather, the effects may manifest in the long-term fitness reduction of the host (Willis & Poulin 1999). Although we could not detect any clinical signs of infection, parasite-host relationships that are initially commensal may later affect the body condition when intrinsic and ecological contributing factors cause increased stress.

In the light of this study, the importance of analyzing and examining the synergistic effects between favoring factors and parasite infection on body conditions deserves a great deal of attention in conservation. The multiple infections suffered by individuals in poor condition provide a very important source for the transmission of parasites. In summary, we have been able to show the mechanism of parasitic ecology of a species of nocturnal lemur.

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Appendix 1. Result of PCA for the calculation of VI.

Total variance explained						
Component	Proper initial value			Sum extracted from the square changes		
	Total	% of variance	% cumulative	Total	% of variance	% cumulative
1	2.45	48.32	48.32	2.42	48.32	48.32
2	0.94	18.83	67.16			
3	0.60	11.79	78.94			
4	0.56	11.25	90.19			
5	0.49	9.81	100.00			

Extraction methods: Principal component analysis.

Component matrix	
	Component [a]
	1
Circumference of the base of tail	0.74
Circumference of the mid tail	0.55
Circumference of thigh	0.69
Circumference of the biceps	0.74
Body volume	0.75

Extraction method: Principal component analysis.

a. component extracted

Appendix 2. Mean eggs per gram of feces for Strongyloides and Hymenolepis, Mean of oocyst per gram of feces for Coccidia, mean of lice for ectoparasite, mean parasite species richness.

		Strongyloides sp.	*Hymenolepis* sp.	*Lemurpediculus verruculosus*	Coccidia	PSR
	N	Mean (min–max)	Mean (min–max)	Mean (min–max)	Mean (min–max)	Mean (min–max)
Sex						
F	87	278	13	3	11	1
		(0–4388)	(0–247)	(0–90)	(0–580)	(0–4)
M	**117**	**287**	**78**	**21**	**29**	**3**
		(0–3900)	(0–1000)	(0–145)	(0–950)	(0–5)
Site						
Campsite	71	242	24	5	6	2
		(0–2660)	(0–965)	(0–70)	(0–160)	(0–4)
Talatakely	119	256	**71**	**19**	10	2
		(0–3900)	(0–1000)	(0–145)	(0–245)	(0–4)
Ranofady	**14**	**724**	4	1	**199**	2
		(0–4388)	(0–50)	(0–6)	(0–950)	(0–5)
Period						
1	62	80	53	12	2	2
		(0–556)	(0–965)	(0–120)	(0–20)	(0–4)
2	**65**	**251**	**66**	**17**	**8**	**2**
		(0–1259)	(0–1000)	(0–145)	(0–160)	(0–4)
3	77	465	36	10	48	2
		(0–4388)	(0–518)	(0–140)	(0–950)	(0–4)
Year of study						
2012	120	155	80	16	8	2
		(0–2660)	(0–1000)	(0–145)	(0–160)	(0–4)
2013	47	239	0	13	3	1
		(0–1242)	0	(0–120)	(0–87)	(0–3)
2015	**37**	**754**	16	2	88	2
		(0–4388)	(0–217)	(0–40)	(0–950)	(0–5)

Min - minimum value | max - maximum value | PSR - Parasite Species Richness | period1: before mating season | period2: during mating season | period3: after mating season.

Appendix 3. Result of PCA for the parasites abundance collinear.

Total variance explained						
Component	Proper initial value			Sum extracted from the square changes		
	Total	% of variance	% cumulative	Total	% of variance	% cumulative
1	2.32	57.96	57.96	2.32	57.96	57.96
2	0.71	17.71	75.67			
3	0.59	14.76	90.44			
4	0.38	9.56	100.00			
Extraction methods : Principal component analysis..						

Component matrix [a]	
	Component [a]
	1
Oocyste per gram of feces for Coccidia	0.69
Eggs per gram of feces for *Strongyloides*	0.78
Eggs per gram of feces for *Ascaris*	0.75
Eggs per gram of feces for *Trichuris*	0.82

Extraction method: Principal component analysis.

a. component extracted.

Appendix 4. Parameters estimated from GLMM to evaluate the variation of the Volume Index in *Microcebus rufus*.

Terms of the model	coefficient	SE	t	p
Volume Index				
Constant	0.32	0.35	0.92	0.361
2012	-0.44	0.40	-1.10	0.273
2013	-1.09	0.55	-2.00	**0.048**
2015 (reference year)	0			
Female	0.50	0.42	1.19	0.236
Male (reference sex)	0			
Period 1	0.70	0.42	1.67	0.096
Period 2	0.23	0.46	0.49	0.623
Period 3	0			
Campsite	0.46	0.50	1.02	0.311
Ranofady	-1.12	0.39	-2.85	**0.005**
Talatakely	0			
PSR	-0.18	0.07	-2.56	**0.012**
Parasite abundance	-0.00	0.11	-0.04	0.971
2012*F	0.07	0.50	0.15	0.884
2012*M	0			
2013*F	1.26	0.54	2.32	**0.022**
2013*M	0			
2015*F	0			
2015*M	0			
2012*period 1	0.14	0.38	0.36	0.718
2012*period 2	0.18	0.47	0.39	0.700
2012*period 3	0			
2013*period 1	0			
2013*period 2	0.16	0.56	0.29	0.773
2013*period 3	0			
2015*period 2	0			
2015*period 3	0			
2012*Campsite	-0.03	0.32	-0.11	0.915
2012*Talatakely	0			
2013*Campsite	0			
2013*Talatakely	0			
2015*Ranofady	0			
2015*Talatakely	0			
F*period 1	-1.05	0.36	-2.95	**0.004**
F*period 2	-0.92	0.32	-2.86	**0.005**
F*period 3	0			
M*period 1	0			
M*period 2	0			
M*period 3	0			

SE: Standard Error, *t*: Student test, *p*: probability, F: female, M: male, period 1: before mating season, period 2: during mating season, period 3: after mating season, PSR: Parasite Species Richness.

Appendix 5. Parameters estimated from GLMM to assess body condition index (CI) variation in *Microcebus rufus*.

Terms of the model	coefficient	SE	t	p
Condition Index				
Constant	3.09	1.01	3.07	**0.003**
2012	-3.75	1.14	-3.30	**0.001**
2013	-4.39	1.29	-3.40	**0.001**
2015 (reference year)	0			
Femelle	-0.73	1.25	-0.58	0.562
Male (reference sex)	0			
Period 1	-0.13	0.67	-0.20	0.840
Period 2	-0.74	1.32	-0.56	0.578
Period 3	0			
Campsite	-0.64	1.07	-0.60	0.550
Ranofady	-6.45	1.19	-5.44	**0.000**
Talatakely	0			
PSR	0.03	0.13	0.23	0.822
Parasite abundance	0.60	0.29	2.04	**0.043**
2012*F	0.66	1.48	0.45	0.655
2012*M	0			
2013*F	3.69	1.52	2.43	**0.016**
2013*M	0			
2015*F	0			
2015*M	0			
2012*period 1	0.03	0.60	0.05	0.957
2012*period 2	0.91	1.32	0.69	0.491
2012*period 3	0			
2013*period 1	0			
2013*period 2	1.03	1.41	0.73	0.467
2013*period 3	0			
2015*period 2	0			
2015*period 3	0			
2012*campsite	0.78	0.52	1.49	0.138
2012*Talatakely	0			
2013*campsite	0			
2013*Talatakely	0			
2015*Ranofady	0			
2015*Talatakely	0			
F*period 1	-0.46	0.54	-0.85	0.399
F*period 2	-0.08	0.53	-0.15	0.884
F*period 3	0			
M*period 1	0			
M*period 2	0			
M*period 3	0			

SE - Standard Error | *t* - Student test | *p* - probability | F - female | M - male | period 1 - before mating season | period 2 - during mating season | period 3 - after mating season | PSR - Parasite Species Richness.

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PLATINUM
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Identification of suitable habitat for Swamp Deer *Rucervus duvaucelii duvaucelii* (Mammalia: Artiodactyla: Cervidae) in Chitwan National Park, Nepal

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Abstract: Swamp Deer is a globally threatened large-sized deer species confined within small patches of the Indian subcontinent. Historically, Swamp Deer occurred in Chitwan National Park, Nepal but was extirpated in the 1960s primarily due to widespread hunting. We assessed the habitat suitability at present for the Swamp Deer in Chitwan National Park using multi-criteria analysis in GIS and vegetation assessment using frequency, dominance, and cover. Within the 952.63km^2 area of the national park, the habitat suitability analysis identified 14.57km^2 as highly suitable, 134.87km^2 as suitable, and 803.19km^2 as moderate to least suitable area. Most of the national park's grassland is suitable for Swamp Deer. Grassland is dominated by *Saccharum* spp.; *Imperata cylindrica* is the most widely distributed grass species followed by *Saccharum* spp., *Narenga porphyrocoma*, and *Apluda mutica*. Grass species of the Poaceae family are the most preferred species by Swamp Deer, which are found within short grasslands. The study revealed that Padampur Phanta could be the most suitable site for the reintroduction of Swamp Deer due to its highest proportion of short grass and availability of preferred food species and good habitat in comparison to other blocks. Invasion of swamps of Chitwan by *Mikania micrantha* and *Eichornia crassipes* could be a limiting factor for the habitat suitability of Swamp Deer.

Keywords: AHP, grassland, habitat suitability, invasive species, Poaceae, reintroduction, vegetation assessment.

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INTRODUCTION

Swamp Deer *Rucervus duvaucelii* is listed as Vulnerable in the IUCN Red List and included in Appendix I of CITES. The species is distributed in isolated pockets of the Indian subcontinent with an estimated total population between 3,500 and 5,100 individuals. The altitude range of Swamp Deer is 100–300 m (Duckworth et al. 2015). Groves (1982) identified three subspecies of Swamp Deer, namely, *R. d. duvaucelii*, *R. d. branderi*, and *R. d. ranjitsinhi*. *Rucervus duvaucelii duvaucelii* is distributed in the Indo-Gangetic plain north of the Ganges, including Nepal and parts of India. *Rucervus duvaucelii branderi* is distributed between the Ganges and Godavari rivers in central India and *Rucervus duvaucelii ranjitsinhi* in the Brahmaputra floodplain in eastern India. The subspecies *R. d. duvaucelii* became extinct from Pakistan and *R. d. ranjitsinhi* from Bangaladesh (Qureshi et al. 2004). Historically, the Swamp Deer was distributed in swampy grasslands throughout the Terai of Nepal (Mishra 1982; Gurung 1983). The remaining population of Swamp Deer is now limited to Bardia National Park (BNP) supporting 106 individuals and Shuklaphanta National Park (ShNP) supporting 2,300 individuals in the western Terai. The population in ShNP holds the world's largest herd of Swamp Deer (Poudel 2007; DNPWC 2015) and establishes the site as globally important for its conservation.

In contrast, the Swamp Deer populations in BNP and ShNP face continuous food shortage, disease, and other anthropogenic stresses (Poudel 2007). Small and isolated populations are much more likely to go extinct due to demographic stochasticity, environment stochasticity, and genetic drift, or simply by chance events. Therefore, identification of potential habitats and establishing new populations through translocation are necessary for the long-term survival of this species.

Swamp Deer (Image 1) is primarily a grazer species (Pokheral 1996) which strongly prefers short grasslands (Bhattarai 2015). Swampy grasslands are considered the prime habitat of this species with the exception of *R. d. branderi*. Swamp Deer mostly feed on grass species and occasionally on aquatic plants (Moe 1994). Some of the most utilized food species are *Saccharum* spp., *Imperata cylindrica*, *Cynodon dactylon*, *Narenga porphyrocoma*, *Phragmites karka*, *Oryza rufipogon*, *Hygroryza* spp., and *Hydrilla* spp. (Martin 1977; Moe 1994; Pokheral 1996; Bhatta 2008; Bhattarai 2015), with the highest preference for *I. cylindrica* followed by *C. dactylon* and *Saccharum* spp. (*S. sponataneum, S. bengalense*, and *S. munj*) (Bhatta 2008; Bhattarai 2015). Swamp Deer use riverine forest for resting, but were never recorded there while feeding (Bhatta 2008; Bhattarai 2015). Swamp Deer usually avoid thick forested areas (Pokheral 1996); even the thickets of *Phragmites karka* were avoided by the species in all seasons in Jhilmil Jheel Conservation Reserve (JJCR), Uttarakhand, India. Similarly, Swamp Deer avoid riverine forests where there is a lack of water and preferred edible plants (Gyawali & Jnawali 2005).

Image 1. Swamp Deer *Rucervus duvaucelii*

Swamp Deer use water for drinking at least two times a day in winter and in monsoon but three times or more in summer (Bhatta 2008). Similarly, this species shows a high preference for grassland plots with water holes (Bhattarai 2015). On an average, Swamp Deer move 2–3 km a day (Martin 1977; Qureshi et al. 1995); therefore, water sources should be located within the daily range of the species.

The suitable habitat of a species can be assessed based on the availability of the food, water, cover, and space needed for the species. Habitat suitability index (HSI) modelling is one of the widely accepted methods used to assess habitat for the translocation/ reintroduction of species. Such assessment analyzes the relations of the species with their habitat (Guisan & Zimmermann 2000). A quantitative measurement through systematic ground surveys is a traditional and resource-intensive approach for obtaining information about the habitat. Geospatial technology can supplement such intensive survey methods (Nandy et al. 2012). Habitat suitability modelling was used in different areas throughout the world to determine potential sites for the translocation and restoration of different species. In Nepal, habitat suitability modelling was applied for the Snow Leopard *Panthera uncia* in western Nepal, One-horned Rhinoceros *Rhinoceros unicornis* in Chitwan National

Park, and Tiger *Panthera tigris* in Triyuga Forest (Jackson & Ahlborn 1984; Kafley et al. 2009; Aryal 2016), but not for the Swamp Deer. Nandy et al. (2011) used multi-criteria analysis in GIS to identify the potential habitat for *R. d. duvaucelii* in JJRC. Similarly, Singh et al. (2015) used Environmental niche modelling for habitat suitability analysis of *R. d. branderi* in Madhya Pradesh, India. In this study, we used multi-criteria analysis to identify the potentially suitable habitat for the reintroduction of *R. d. duvaucelii* in Chitwan National Park (CNP) based on vegetation composition of grassland blocks and riverine forest patches. The study is intended to provide useful information for wildlife managers, conservation officers, and government authorities.

METHODS

Study Area

CNP is the first national park of Nepal (Bhuju et al. 2007) and was established in 1973 covering an area of 952.63km^2, 27.282–27.703 ^{0}N & 83.839–84.773 ^{0}E) surrounded by an additional 750km^2 buffer zone (Fig. 1). The vegetation of CNP consists of tropical to subtropical forests with mosaics of successional communities at different stages in alluvial floodplains, including *Bombax ceiba-Trewia nudiflora* riverine forest to climax *Shorea robusta* (Thapa 2013; CNP 2015a). Most of the national park grasslands are dominated by *Saccharum* spp. The park is home to many rare and threatened species including Tiger *Panthera tigris*, Indian Rhinoceros *Rhinoceros unicornis*, Asian Elephant *Elephas maximus,* Gaur *Bos gaurus,* Sloth Bear *Ursus ursinus,* South Asian River Dolphin *Platanista gangetica,* Bengal Florican *Houbaropsis bengalensis,* and Gharial *Gavialis gangeticus* (CNP 2015a). The park is distributed at an altitude of 150–850 m (CNP 2015b).

Habitat Survey Sample Design

The park area was divided into three strata: grassland (including swampy areas and wetlands), riverine forest, and other forest land. Floristic composition of vegetation was assessed in the preferred habitats of Swamp Deer (grassland and riverine forest). To represent the grasslands of Chitwan adequately, the three largest patches, namely, Padampur Phanta (PP), Bhawanipur-

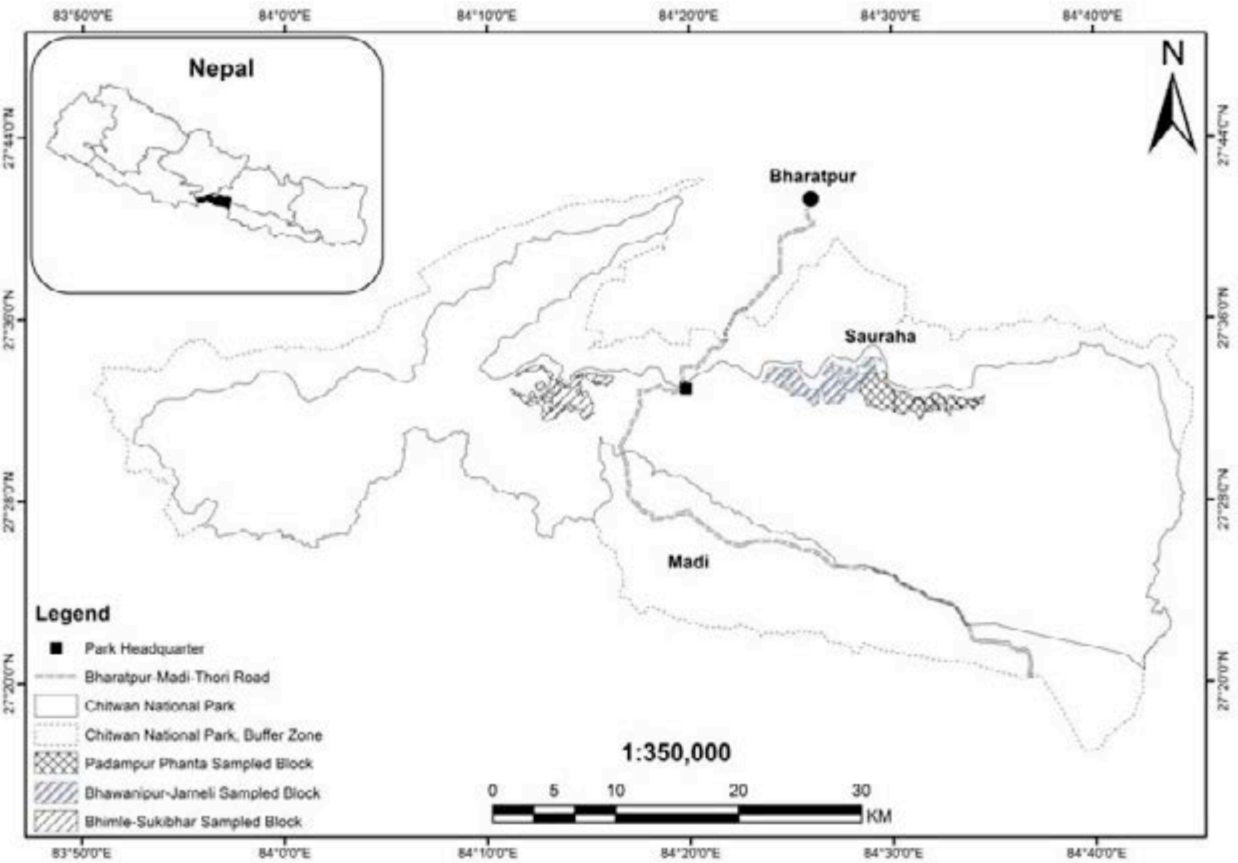

Figure 1. Sample study blocks in Chitwan National Park, Nepal.

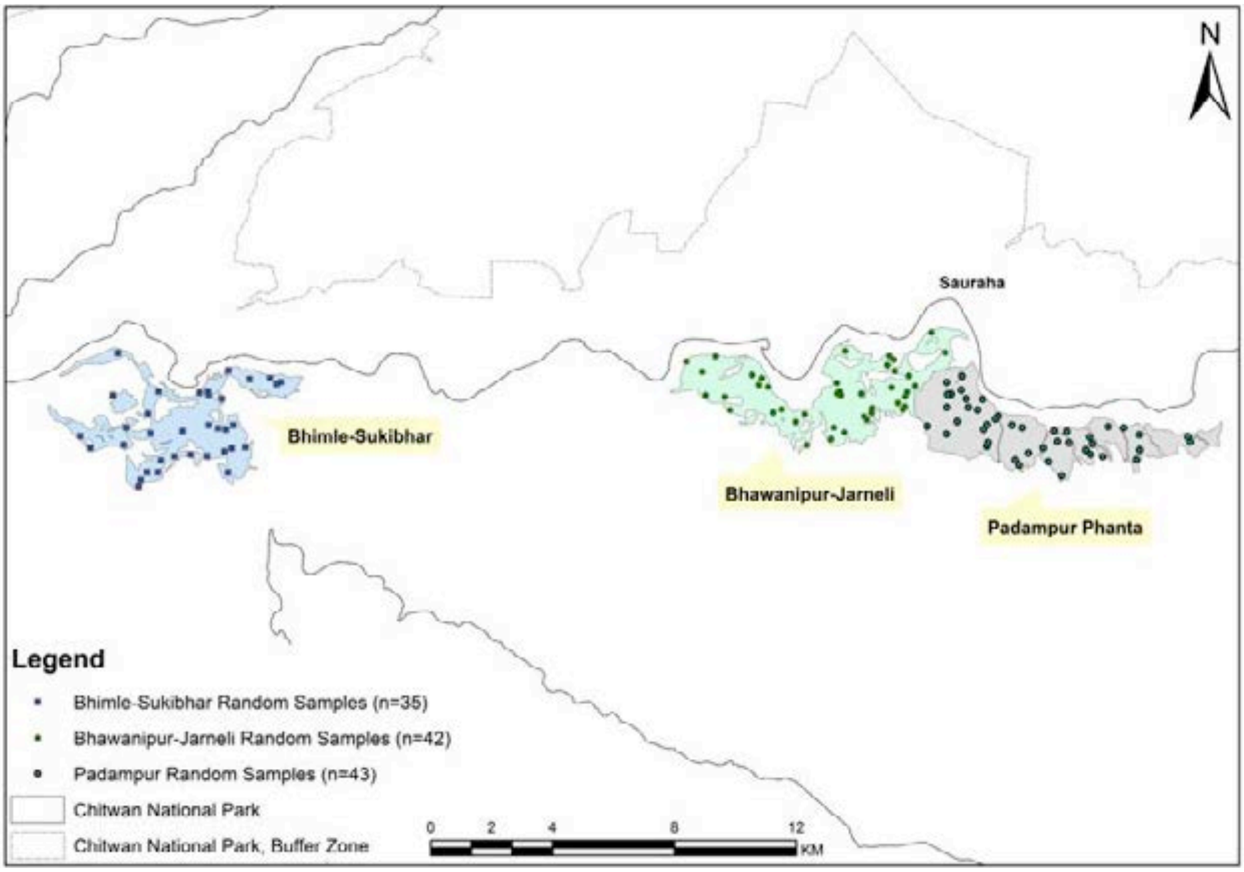

Figure 2. Random sample points in study blocks in Chitwan National Park, Nepal.

Jarneli (BJ), and Bhimle-Sukibhar (BS), were selected for field sampling. A total of 120 random sample points were set out proportionately in these grasslands (Fig. 2). Similarly, nine sample points were laid systematically (at 400m interval) in the riverine forest in the eastern sector of CNP, which starts from Sauraha.

Vegetation assessment in each sampling plot within the grassland blocks was carried out using 1m×1m quadrats (Oosting 1956). Frequency, dominance, and cover were used to assess the vegetation status. During the study, the team failed to study the density of grassland plots due to the dominance of tall grass species (>3m) in the park. Therefore, the ocular method was used to estimate the frequency, dominance, and cover in the grassland. In riverine forest patches, density, frequency, abundance, and cover were studied using nested quadrats of 20m×25m, 10m×10m, 5m×5m, and 1m×1m for poles having a diameter more than 29.99cm, trees having a diameter 10–29.99 cm, herbs having a diameter less than 10cm, and shrubs having heights less than 1m (CFD 2004).

GIS data collection/ preparation

The national park boundary layer was obtained from the department of survey (DoS), Nepal. Landsat-8 satellite images of March 2016 were used to obtain the updated land cover (or habitat type) of the park area. Supervised image classification using 253 training sample points collected from the field study was used with maximum likelihood approach. The image was classified into six land cover categories, namely, river, riverbank, riverine forest, forest, grassland, and bushes with 76.67% accuracy. The classification shows 692.47km^2 (72.69%) of the park area is covered by *Shorea robusta* and mixed forest, 112.80km^2 (11.84%) by grasslands, and 93.45km^2 (9.81%) by riverine forest. A small part of the park is covered by riverbank (32.10km^2, 3.37%), water bodies (18.86km^2, 1.97%), and bushes (2.95km^2, 0.31%). The land cover classification map is shown in Fig. 3.

Suitability Analysis

The land use classified raster image was used in suitability analysis. Water source, road, settlement, and vegetation type/land use thematic layers were rated into

Table 1. HQR for vegetation types/ land use and distance to water, road, and settlement.

	Vegetation type/ land use	HQR
1	Sal forest and other forest	4
2	Riverine forest	3
3	Waterbodies	2
4	Grassland	1
5	Bushes/ shrubs	3
6	Riverbed	2
	Distance to water (m)	**HQR**
1	<500	1
2	500–1000	2
3	1000–2000	3
4	>2000	4
	Distance to road (m)	**HQR**
1	<1000	4
2	1000–2000	3
3	2000–3000	2
4	>3000	1
	Distance to settlement (m)	**HQR**
1	<1000	4
2	1000–2000	3
3	2000–3000	2
4	>3000	1
1 - highly suitable, 2 - suitable, 3 - moderately suitable, 4 - least suitable.		

habitat values by assigning habitat quality rating (HQR) based on their suitability on a scale in decreasing order of suitability (1 for highly suitable and 4 for least suitable) (Nandy et al. 2012). The area close to a water source was considered to be highly suitable and the area close to district/feeder road or settlement was considered to be least suitable due to high human interference. The different thematic layers were adopted from Nandy et al. (2012) and modifications were made in HQR based on findings of Bhattarai (2015). HQR for distance to water was modified with expert judgment from less than 1000m to less than 500m for highly suitable, 500m to 1000m for suitable category, 1000m to 2000m for moderately suitable, and more than 2000m for least suitable category. Similarly, the park area having an elevation greater than 300m was considered least suitable. HQR is given in Table 1.

After rating all thematic layers into 1 to 4 suitability classes, a weighted sum was done in GIS environment. Weights were assigned to different layers by using a decision-aiding tool, analytical hierarchy process (AHP) (Saaty 1987), and weights were given using Nandy et al. (2012) and modified with site condition. Pair-wise comparison matrix of variables vegetation types/ land use, water source, road, and settlement was carried out and is shown in Table 2. Vegetation type and water source are essential habitat factors and road and settlements are disturbance factors. During the evaluation process, more weight was given to vegetation type/ land cover and then to water bodies, while less weight was given to road and settlement. Between road and settlement, more weight was assigned to road as a district road (Bharatpur-Madi-Thori) crosses the national park core region from Kasara to Bankatta and all of the settlement lies outside the natural river boundary which separates the national park core region from its buffer zone.

The pair-wise matrix was then synthesized to standardize by dividing each element of the matrix by its column value total. The priority vector was obtained by averaging row in Table 3.

Table 2. Pair-wise comparison matrix.

Class [C]	Vegetation types/ land use	Water source	Road	Settlement
Vegetation types/ land use	1	3	5	7
Water source	1/3	1	3	5
Road	1/5	1/3	1	3
Settlement	1/7	1/5	1/3	1
Total	1.676	4.533	9.333	16.00

Table 3. Synthesized matrix.

Class	Vegetation types/ land use	Water source	Road	Settlement	Priority vector (W)
Vegetation types/ land use	0.597	0.662	0.536	0.438	0.558
Water source	0.199	0.221	0.321	0.313	0.263
Road	0.119	0.073	0.107	0.188	0.122
Settlement	0.085	0.044	0.036	0.063	0.057
					∑W = 1

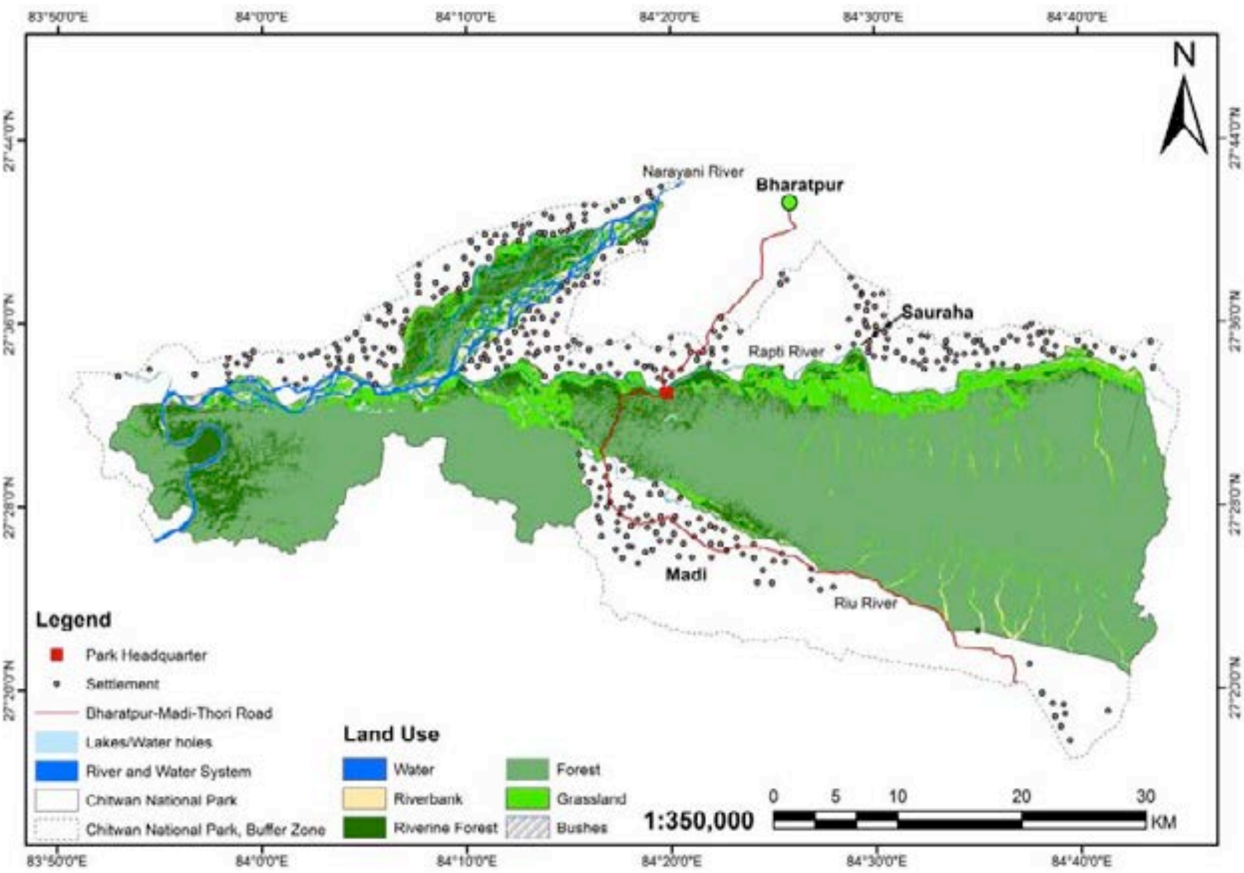

Figure 3. Land use in Chitwan National Park, Nepal.

The consistency ratio (CR) of the pair-wise comparison matrix was 0.043. The CR less than 0.1 is accepted according to Saaty's principle (Saaty 1987). To calculate consistency ratio, consistency index (CI) was calculated and random index (RI) was derived from Saaty's index.

The weights of different variables, obtained from the above analysis, were used in the weighted suitability to evaluate the suitable habitat for Swamp Deer. The HSI is calculated as

$$HSI = 0.558\times VLI + 0.263\times WI + 0.122\times RI + 0.057\times SI$$

where VLI = vegetation type/land use Index, WI = water source index, RI = road index, SI = settlement index.

RESULTS

Habitat Suitability

The habitat suitability analysis showed that about 14.57km^2 (1.53%) of CNP was found to be highly suitable, 134.87km^2 (14.16%) suitable, 203.89km^2 (21.40%) moderately suitable, and 599.30km^2 (62.91%) least suitable for Swamp Deer. Most of the grassland of CNP falls into the suitable to highly suitable categories. The distribution of the areas with varying degrees of suitability is shown in Fig. 4.

According to the land use types, 100.14km^2 (67.01%) area of grassland, 25.72km^2 (17.21%) of riverbank, 16.64km^2 (11.14%) of water bodies, 4.46km^2 (2.99%) of forest (other than riverine), 1.86km^2 (1.25%) of riverine forest, and 0.62km^2 (0.41%) of bushes of CNP was found under suitable to highly suitable category.

Similar proportion of highly suitable to suitable area was found in all three studied blocks; however, the highest area was found in BS followed by BJ and PP grassland blocks. Some small patches were also identified as highly suitable west of BS and east of PP (Table 4).

Habitat Composition

Grassland: Among the 120 quadrats sampled, 90% (n=108) sample points were distributed in grassland, 8.33% (n=10) in forest, and 1.67% (n=2) in bushes. Of the 108 grassland quadrats, 20.37% (n=22) were found to be of short grass (<3m) and 79.63% (n=86) of tall grass (>3m). The highest proportion of tall grassland was

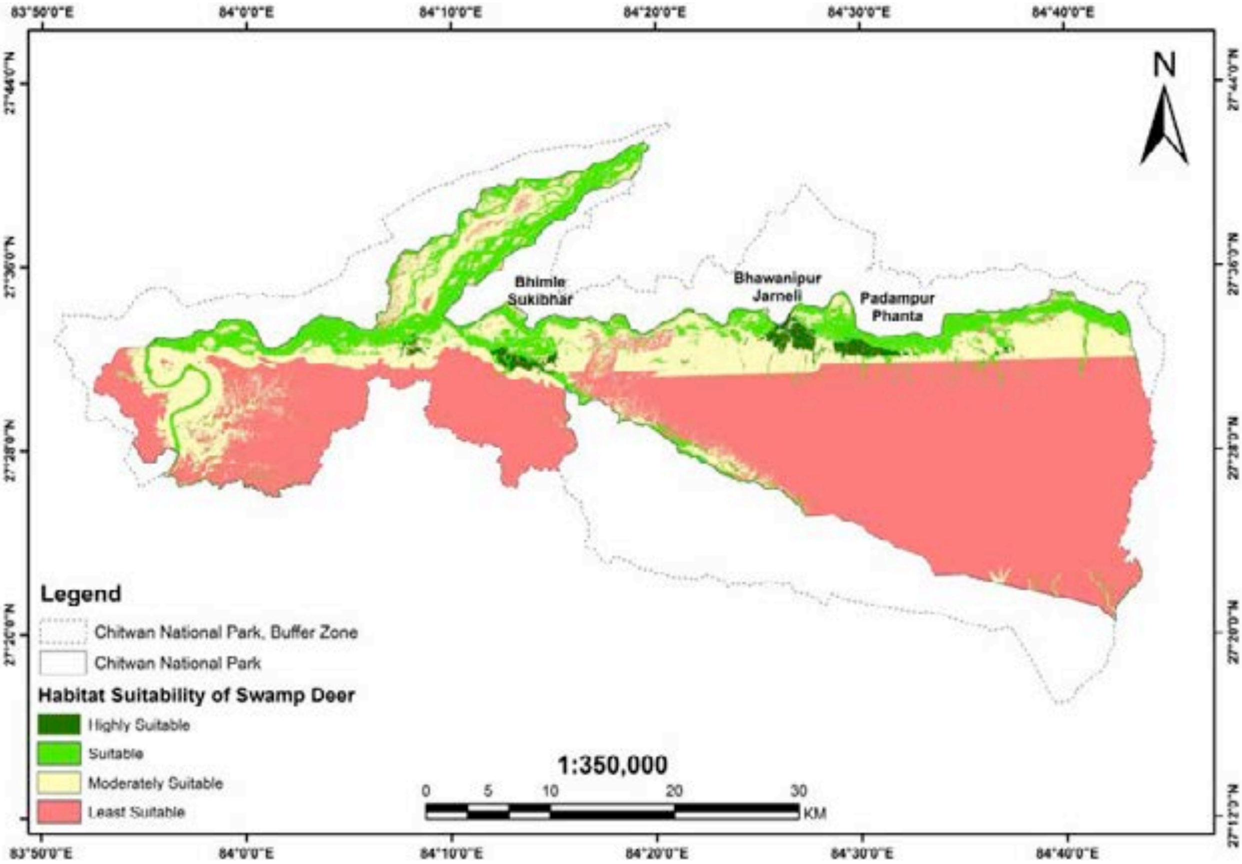

Figure 4. Potential habitats of Swamp Deer in Chitwan National Park, Nepal.

Table 4. Patch-wise habitat suitability in the study area (in km^2) in Chitwan National Park, Nepal.

Block	Highly suitable	Suitable	Moderately suitable	Least suitable	Total area
Padampur Phanta	3.49	9.60	0.26	0.01	13.37
Bhawanipur-Jarneli	4.99	8.49	0.38	0.01	13.86
Bhimle-Sukibhar	2.93	11.07	0.30	0.02	14.31
Others	3.16	105.71	202.95	599.27	911.09
Total area	14.57	134.87	203.89	599.30	952.63

found in BJ (97.06%, n=33) and the lowest in PP (70.73%, n=29). Most of the short grassland quadrats observed (n=9) at BS grassland were located on the banks of the Rewa and Rapti rivers. Frequency analysis revealed *Imperata cylindrica* as the most common species with a frequency of 96.13% (n=105) followed by *Saccharum arundinaceum*, *Narenga porphyrocoma*, *Apluda mutica*, and *Cynodon dactylon*. *Saccharum arundinaceum* (54.63%) was found to be the most dominant grass species in the study area followed by *N. porphyrocoma*, *I. cylindrical*, and *Themeda* spp. All of the study quadrats had areas more than 80% covered by grass species. The swampy areas and waterholes of the park were covered by *Mikania micrantha* and *Eichornia crassipes*. The block-wise dominant and co-dominant species are given in Table 5. During frequency and dominance calculations, species whose occurrence was less than 5% of the total number of quadrats were eliminated due to insignificant occurrence (Table 5).

Riverine Forest: The highest density (0.01, 0.42, 0.11, and 0.89), frequency (100, 100, 100, and 77.79), and abundance (2.33, 4.22, 2.78, and 1.43) in riverine forest were found on *Trewia nudiflora* in nested quadrat of 20mx25m, 10mx10m, 5mx5m, and 1mx1m area. Most of the sample plots (80%) in riverine forest were found to be an association of *T. nudiflora* and *Bombax*

Table 5. Dominance of grass species in the studied blocks in Chitwan National Park, Nepal.

Block	Dominant species	Occurrence in %	Co-dominant species	Occurrence in %
Padampur (41 quadrats)	*Saccharum arundinaceum*	46.34	*Narenga porphyrocoma*	36.59
	Imperata cylindrica	24.39	*Saccharum arundinaceum*	14.63
	Narenga porphyrocoma	21.95	*Apluda mutica*	14.63
			Bothriochloa interrnedia	9.76
			Saccharum bengalensis	7.32
Bhawanipur-Jarneli (34 quadrats)	*Saccharum arundinaceum*	67.65	*Narenga porphyrocoma*	32.35
	Narenga porphyrocoma	20.59	*Saccharum bengalensis*	20.59
	Themeda spp.	5.88	*Apluda mutica*	20.59
			Saccharum arundinaceum	14.71
			Imperata cylindrica	5.88
Bhimle-Sukibhar (33 quadrats)	*Saccharum arundinaceum*	51.52	*Narenga porphyrocoma*	33.33
	Imperata cylindrica	21.21	*Imperata cylindrica*	15.15
	Narenga porphyrocoma	18.18	*Themeda* spp.	15.15
			Saccharum bengalensis	12.12
			Saccharum spontaneum	9.09
			Apluda mutica	6.06

ceiba. Similarly, *Ehretia laevis* and *Litsea monopetala* were also found frequently in the riverine forest. *Murrya koenigii* and *Toona ciliata* saplings were found on 30% and 10% plots, respectively. The seedlings of *T. nudiflora*, *L. monopetala*, *M. koinegii*, and *E. laevis* and invasive species *Mikania micrantha* and *Lantana camara* were also observed in the studied quadrats. An average of 75% crown coverage and 50% ground coverage was estimated in riverine forest patches.

DISCUSSION

The GIS based multi-criteria study identified 149.44km^2 (15.69%) as suitable of which 40.57km^2 (4.26%) lies in three major grasslands. This constitutes 97.67% of the total area of these three major grasslands. BS (14km^2) has the largest area of suitable habitat followed by BJ (13.48km^2) and PP (13.10km^2). Habitat suitability was mostly influenced by the presence of water sources and vegetation types. In addition to the above-mentioned grasslands, most of the other grassland patches were also found suitable which includes the floodplain of three major river systems of the park, namely, Rapti, Rewa, and Narayani. The highly suitable area of both PP and BJ grasslands are distant from Rapti River and most of the BJ grassland is bordered by riverine forest. On the other hand, the highly suitable area of BS falls on the river bank of Rewa and the suitable area is extended along the bank of Rapti River. All of the suitable category habitat areas have a risk of inundation and flooding during rainy season. The BS grassland, however, has a high risk of flooding. Similarly, BS is separated from the eastern grasslands (PP and BJ) by *Shorea robusta* forest and the Bharatpur-Madi-Thori District Road, which possibly restricts the movement of Swamp Deer. There is, however, the possibility of joining BS with suitable grassland patches that are uniformly distributed in the western part.

The study of vegetation composition in the quadrats showed that 20.37% area of the three grassland blocks is covered by short grasses. According to previous studies, short grasslands, rivers, and riverbeds are the most preferred habitat of Swamp Deer. In the study area, *I. cylindrica*, *C. dactylon, S. spontaneum, S. bengalensis, D. bipinnata*, *Phragmites karka*, *Cyperus* spp., *N. porphyrocoma*, *Themeda* spp., *Apluda mutica*, *Hemartha compressa,* and *Arundinella nepalensis* were reported as food species of Swamp Deer by previous researchers. This study also found *I. cylindrica* as the most commonly distributed grass species followed by *S. arundinaceum* and *N. porphyrocoma* in the park. The availability of the most preferred food species *I. cylindrica* increases the suitability of the area which is dominant only in 16.67% of the quadrats. In contrast, most of the grasslands are dominated by *S. arundinaceum* (54.63%) which will be least suitable after growth in summer (April–June).

If there is a decision to reintroduce Swamp Deer in CNP, PP has the highest proportion of short grassland and dominance of *I. cylindrica*, and therefore could be selected based on vegetation, however, this area (PP) bears challenges of inundation and flooding due to proximity to a perennial river system. Study quadrats in BJ had 97.06% tall grassland, thus, it would be favourable to Swamp Deer only from February to April when grass sprouts start to emerge. BS grassland is dominated by tall grass species (72.73%) and most of the short grasses are distributed along the Rewa and Rapti rivers. In case of heavy flooding and inundation, there is a risk of these grassland patches being modified. Hence, for this area to be appropriate for the reintroduction of Swamp Deer, habitat management interventions are required around Bhimle and Sukibhar posts.

All of the grasslands of CNP lie in close proximity to Rapti, Rewa, and Narayani rivers. Similarly, in some areas, park management developed water holes which provide water to wildlife species. All of the suitable areas of CNP lie within a 2km-distance to a water source and are, therefore, within the daily range of the Swamp Deer.

For the viability of the species, sufficient numbers of individuals need to be reintroduced. Previous studies on Swamp Deer were mainly focused on habitat preference, food and feeding behaviour, and herd size and there is no information available on the area required for this species. The study from JJCR found that 14km^2 is insufficient for 134 Swamp Deer (Nandy et al. 2012) and 0.009km^2 area per individual is insufficient in maintaining a viable population. We believe that the suitable area identified by this study can support only a small population as described by Nandy et al. (2012) based on study in JJCR. We, however, would like to recommend a more detailed study regarding population viability.

This study and previous studies by Ram (2014) and Lamichhane et al. (2014) in CNP showed that the national park is severely affected by the invasion of *Mikania micrantha*, a mile-a-minute invasive species. The intensity of *M. micrantha* invasion is greatest in and around sources of water. Most of the swampy grassland area is invaded by this species. There is no information available on the response of Swamp Deer to *M. micrantha* up to now, but this invasive species could have a strong impact by limiting food availability. In addition to invasive species, several other environment factors (such as population density, social organization, prey-predator relationship, ungulate species relationship, and risk assessment) could affect the suitability of an area for the reintroduction of the species and these were not assessed in this study. Further research on these topics is recommended.

CONCLUSION

Habitat suitability assessment using multi-criteria analysis in a GIS environment showed 149.44km^2 of the park area provides suitable habitat for Swamp Deer in CNP including 100.14km^2 grassland, 25.72km^2 riverbank, 16.64km^2 water bodies, 4.46km^2 forest, 1.86km^2 riverine forest, and 0.62km^2 bushes. A total of 112.80km^2 of the park is grassland. Out of this, we assessed 41.54km^2 area in three major grasslands for the vegetation suitability. Amongst the assessed blocks of grassland, 40.57km^2 was found to be suitable according to the parameters of the study. Considering suitability in terms of habitat size, food, and water availability, PP is found to be more suitable for reintroduction of Swamp Deer compared to the other two sites. Alternatively, BS grassland could be another potential habitat for reintroduction of Swamp Deer with habitat management interventions. BJ has only seasonal suitability due to the high coverage of tall grass species.

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The diversity and conservation of mammals in the Dodo Coastal Forest in southwestern Côte d'Ivoire, western Africa: a preliminary study

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Abstract: To improve the knowledge of non-volant mammal diversity and conservation prospects in the Dodo Coastal Forest (DCF) in southwestern Côte d'Ivoire, we conducted reconnaissance surveys and interviews, and deployed remote cameras. We calculated visual encounter rates (vER) and sign ER (sER) of mammalian taxa and hunting signs, mapped their locations and tested the hypothesis that sightings and signs of primates occurred closer to the river Dodo in and near the gallery forest. We sighted nine taxa, including threatened King Colobus (Endangered, EN), Olive Colobus (Vulnerable, VU), Lowe's Monkey (VU), the Eastern Lesser Spot-nosed Monkey (VU), and White-bellied Pangolin (VU), with vER of 0.04, 0.12, 0.04, 0.12, 0.04, respectively. We confirmed 14 other taxa with signs including threatened Western Chimpanzee (CR), Pygmy Hippopotamus (Endangered, EN), Bosman's Potto (VU), and Black-bellied Pangolin (VU), with sER of 0.51, 0.04, 0.08, 0.04, respectively. The most frequently encountered signs were of the Red River Hog at 1.73 signs/km, and the Bushbuck at 0.63 signs/km. Remote cameras captured images of these two taxa at image capture rates (ICR) of 0.044 and 0.022, respectively. Images of the African Buffalo were captured at ICR of 0.044. The 23 confirmed taxa include seven primates, four rodents, three carnivores, six even-toed ungulates, two pangolins and a Tree Hyrax. The mean distance from the river Dodo to the sightings and the signs of the primates was significantly shorter than that of other taxa. This supports our hypothesis. There was a high level of hunting signs (sER = 0.63) indicating that intensive hunting pressure is menacing the fauna. We recommend that authorities take actions against poaching, install a surveillance program, and curtail charcoal-making to ensure the conservation of the threatened mammals of the DCF.

Keywords: Chimpanzee, encounter rates, gallery forest, King Colobus, river Dodo.

Abbreviations: CF - Classified Forest | CR - Critically Endangered | D - Total distance covered | *d* - distance from the River Dodo to observations (sightings and signs of animals) | DCF - Dodo Coastal Forest | EN - Endangered | FM - Fecal matter | FO - Food remains | FP - Footprints | GPS - Global Positioning System | ICR - Image Capture Rates | IUCN - International Union for Conservation of Nature | N - Frequency of each taxon | NHP - Non-human primates | NPM - Non-primate mammals | NT - Near Threatened | RAI - Relative Abundance Index | RS - Resting Site | sER - sign encounter rates | vER - visual encounter rates | VOC - Vocalization | VU - Vulnerable.

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INTRODUCTION

The forests in Côte d'Ivoire represent the core of the Upper Guinean Forest of western Africa (Bakkar et al. 2004), and they have been experiencing continuous degradation and fragmentation. Between 1981 and 1990, the deforestation rate in Côte d'Ivoire was about 7.6% per year (850km^2/yr), the highest among tropical countries. By 1990 this country had lost about 92.5% of the original 1,50,000km^2 of dense forest, which now consists of about 6.9% of the total area of the country (Chatelain et al. 2004; CILSS 2016). Land conversion is particularly uncontrolled in rural areas, where landowners carry out large-scale conversion of forests into farmlands and plantations, and also sell land for logging and mining purposes. In such a context, the survival of wildlife is greatly threatened (McNeely 2003; Bakayoko et al. 2004; McGraw 2005; Kassé et al. 2006; Wright et al. 2006; Yaokokoré-Beibro et al. 2010; Adou et al. 2011), and anthropogenic activities can lead to extirpation of animal species. It is also clear that hunting poses a great threat to taxa that can survive in disturbed habitats (Matsuda Goodwin et al. 2017a).

Protected areas have played a significant role in the conservation of threatened wildlife and continue to play an important role, however, because a number of threatened species have been locally extirpated from many protected areas, community forests that receive no official protection are increasingly important for wildlife conservation (Porter-Bolland et al. 2012; Butchart et al. 2015; Matsuda Goodwin et al. 2017a). Also, the efficacy of protected areas as conservation sites has been questioned due to the sociological and ecological pressure on these areas during two episodes of civil war experienced by the country (UICN/BRAO 2008; Daskin & Pringle 2018). Thus, improving our knowledge of the faunal diversity outside protected areas has become important, and this knowledge is crucial to understanding the ecosystem services that animals offer (Ahumada et al. 2011; Torres-Porras et al. 2017). Such information is necessary to make sound management decisions to plan conservation programs and determine what types of focused conservation actions should be taken.

Like other unprotected forests in Côte d'Ivoire, the coastal forest at the mouth of the river Dodo, the DCF, has undergone unprecedented changes in land use during the last decade or so (CILSS 2016). Formerly intact dense rainforests have been cleared and fragmented to create farms and plantations for oil palm, rubber, cocoa, coffee, and coconut and the production of charcoal. These anthropogenic activities such as hunting, pet trade, habitat destruction, and habitat degradation threaten faunal diversity (Schipper et al. 2008). The loss of some fauna can cause an irreversible trophic cascade that tips over the ecosystem balance (Estes et al. 2011).

With the exception of studies of marine turtles (Bamba 2002; Peñate 2007), which found at least three species, the faunal diversity of the DCF remains unknown. This preliminary study aims at improving knowledge of the diversity of non-volant mammals, their relative abundance, and spatial distribution in the unprotected coastal forest at the southwestern edge of Côte d'Ivoire. The gallery forest is often the only persisting forest when the surrounding habitat is severely disturbed, and it is an especially important habitat for primates (Galat-Luong & Galat 2005; Granier & Awotwe-Pratt 2007). Thus, we will test the hypothesis that more primates and their signs will be found near the river compared to other mammals. The implications of this study for conservation efforts are also considered.

MATERIALS AND METHODS

Study site

Our study site was the DCF, which lies between 4.500^{0}N–7.183^{0}W and 4.600^{0}N–7.050^{0}W with an area of 4.694ha. It is located at the mouth of the river Dodo at the southwestern edge of Côte d'Ivoire (Fig. 1). The nearest large city, Grand-Béréby, is 18km east of the DCF. The annual rainfall varies from 1700–1900 mm and the mean annual temperature is 24–27 °C (Bohoussou et al. 2018). River Dodo is 56km long with its source in the formerly classified forest (CF) of Haute Dodo and empties into the Atlantic Ocean at Mani-Béréby Village, where it forms the village's sacred wetland forest (Teugels et al. 1988). Villagers perform various ceremonies and trees are somewhat protected, but hunting is allowed. The DCF is one of the few remaining coastal community forests in this region, but it receives no official protection. The forest is limited to the south by the sea and is characterized by the heterogeneity of the habitat. It includes the fallow, rain forest, mangrove, gallery forest, savanna, and coastal thicket that create different ecological niches exploited by a variety of fauna (Teugels et al. 1988). The village is mainly composed of two ethnic groups: the indigenous Kroumen group and the migrants. Both groups practice subsistence farming, hunting, and artisanal fishing.

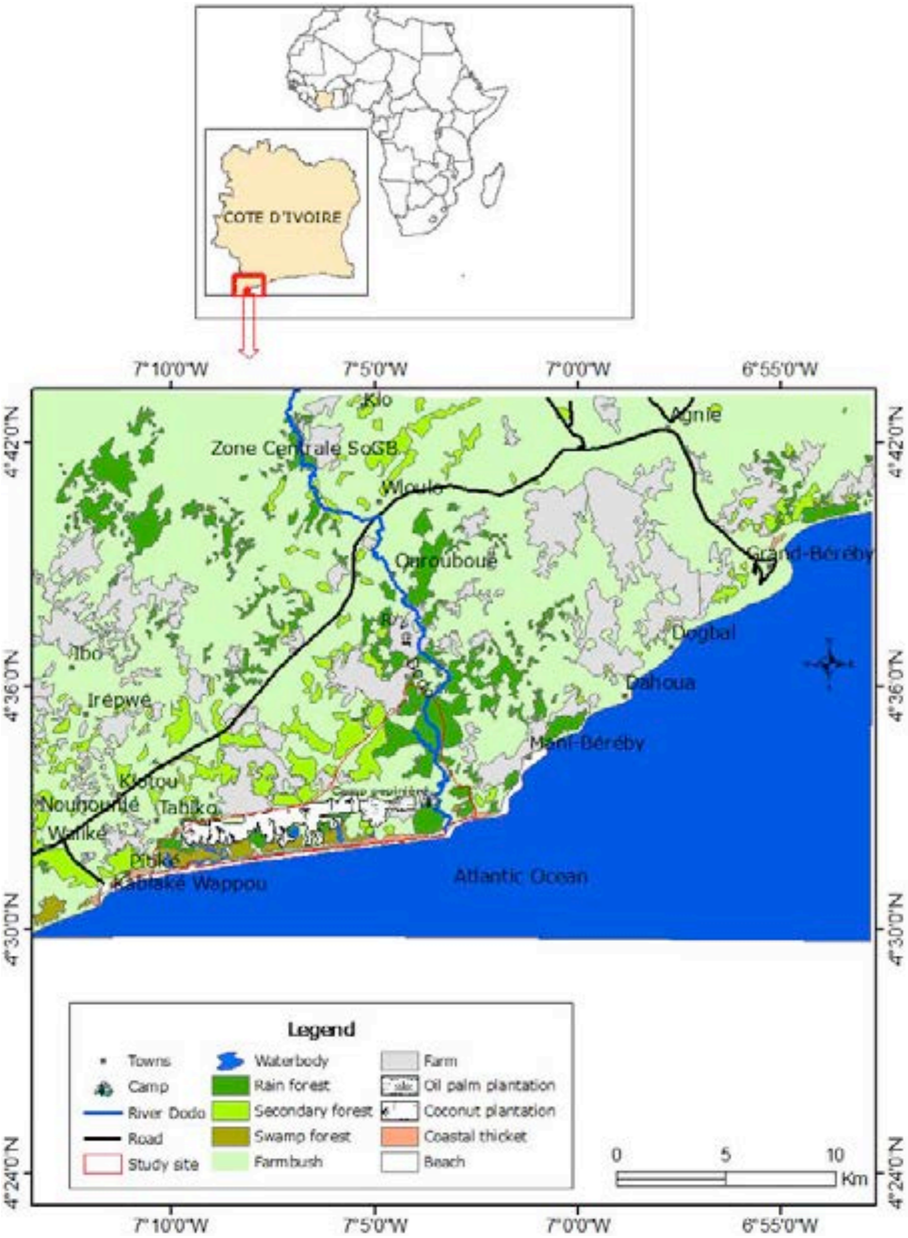

Figure 1. Dodo Coastal Forest (DCF) in southwestern Côte d'Ivoire.

Data collection

We conducted 25.42km of reconnaissance (recce) surveys from 06.00–11.30 h and 15.30–17:00 h between 15 April 2018 and 30 May 2018 (28 days total). We did not use the line transect sampling method, because it requires at least 60 sightings of each taxon for a reliable abundance estimate (Buckland et al. 2001). Recce surveys consisted of walking at a given compass bearing which was in a direction more or less perpendicular to river Dodo, but observers walked following a path of least resistance. We reduced bias by trying to cover the entire study area with an equal interval of one kilometer between paths (Kühl et al. 2008). We recorded the taxon, date, time, GPS coordinates, and distance from the recce origin, and the distance from the river. When we observed chimpanzee nests we also recorded the stage of the nest following Kühl et al. (2008). Additionally, we conducted semi-structured interviews to grasp the local knowledge on the diversity of mammals that still occur and have occurred in the past. The interview is an important method that obtains supplementary information to survey and camera trapping methods. This is particularly true when those methods may fail to detect some rare taxa (Béné et al.

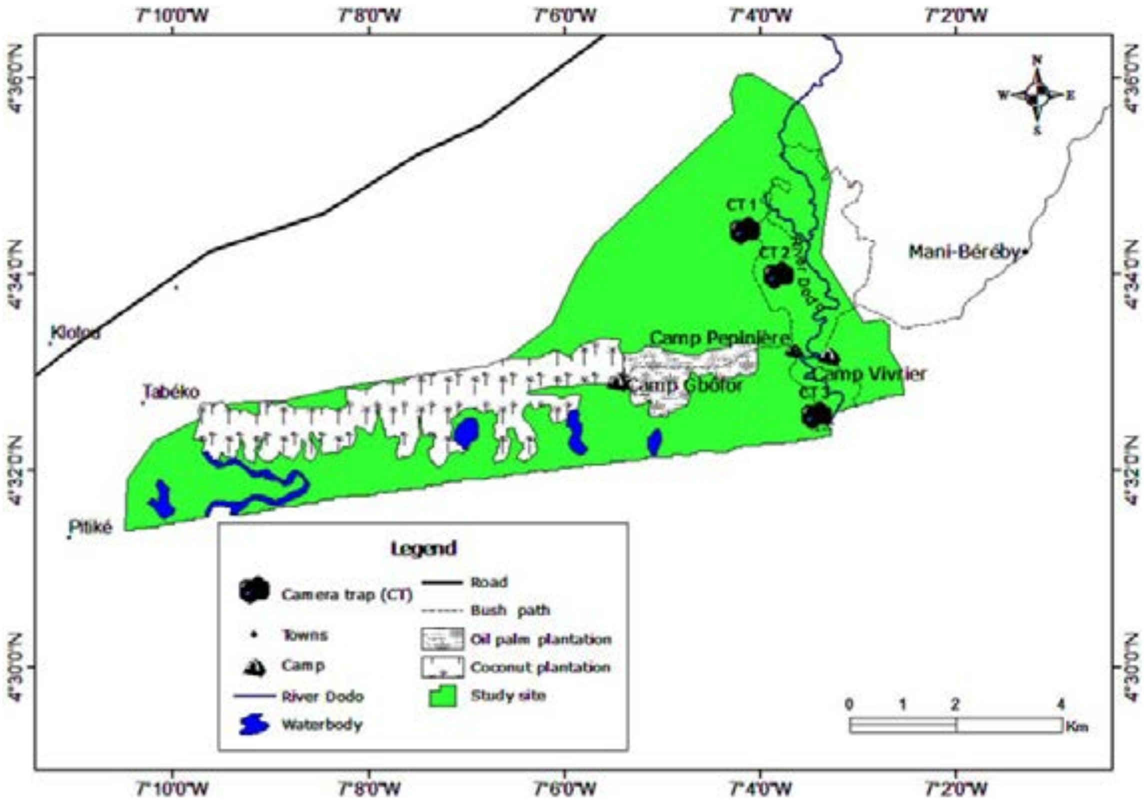

Figure 2. Remote cameras' positions.

2018). We conducted interviews within 2.5km of the study site. The interviewees were asked to give the number and local names of mammalian species that are known to occur in the forest, those observed during the last six months, and wherein the forest they observed them (Matsuda Goodwin et al. 2017b).

Furthermore, we deployed three remote cameras (Bushnell Trophy Cam 119875) at the ground level. More specifically, they were set along the bush paths and under fruiting trees where there was a high probability of capturing images of elusive animals (Cove et al. 2013). The cameras were deployed for 45 days in total (3 cameras x 5 days x 3 locations). To cover different locations in the study site, we moved each camera to other locations at the interval of five days which was defined as a trapping session. The locations of cameras during three trapping sessions are shown in Fig. 2. We compiled the list of mammals that occur at the study site by reviewing the data from the interviews, recce surveys, and remote cameras. Then we verified the most up-to-date conservation status of the confirmed taxa via IUCN Red List version 2018 and also by consulting experts.

Data analysis

To determine relative abundance we calculated encounter rate (ER) of a given taxon using the equation: ER=N/D, where N is the frequency of group sighting or the signs of each taxon while D is the total distance covered during recce walks. We calculated ER for visual sightings (vER) as well as ER for indirect signs (sER) (e.g., vocalization, food remains definitely assignable to certain taxon) of the taxa. Similarly, we also calculated encounter rates of hunting signs (e.g., shotgun cartridge, poacher's camp).

We tabulated presence-absence of taxa from images obtained from remote cameras, and calculated image capture rates (ICR = number of image captured/camera days) for each taxon (Kolowski & Forrester 2017), but we did not obtain the Relative Abundance Index (RAI) as our 45 camera days were fewer than the required 100 (Rovero et al. 2014).

To examine the relationship between the distance from river Dodo to the sightings and signs of the mammalian fauna (*d*) and during the recce surveys, we plotted the geographic coordinates of the sightings and signs using QGIS 2.14 and computed the mean distance of each taxon to the river. Given the importance of gallery forests to the non-human primates (NHP), we tested the hypothesis that *d* of the NHP is shorter than d for the non-primate mammals (NPM). Because the NPM samples did not have a normal distribution based on the Shapiro-Wilk test for normality, we used the Welch Two Sample t-test (Package MASS) (Ripley et al. 2017) to compare the means of non-primate mammals with the mean of all primates as the difference of *d* for the chimpanzees and other primates was not significant. The significance was tested at a two-tailed level. We then created a graph that contrasts *d* between the two groups using ggplot2. All statistics were done using R Studio version 1.1.453 and R version 3.4.4 (R Core Team 2018).

RESULTS

Diversity and ER of taxa and hunting sign ER obtained by surveys

The result of recce surveys is shown in Table 1. We visually confirmed the presence of nine taxa (four Primates, one Carnivora, one Pholidota, three Rodentia) through recce surveys. Among these we observed five threatened taxa: the King Colobus *Colobus polykomos* (EN) (Gonedelé et al. in press), the Olive Colobus *Procolobus verus* (VU) (Oates et al. in press), Lowe's Monkey *Cercopithecus lowei* (VU) (Wiafe et al. in press), the Eastern Lesser Spot-nosed Monkey *Cercopithecus petaurista petaurista* (VU), and the White-bellied Pangolin *Phataginus tricuspis* (VU) (Waterman et al. 2014a) with vER of 0.04, 0.12, 0.04, 0.12, 0.04, respectively. The Olive Colobus and the Eastern Lesser Spot-nosed Monkey were two of the three most frequently observed taxa in addition to the Common Kusimanse *Crossarchus obscurus* (vER = 0.12), which was the only Carnivora taxon sighted during the surveys. Three rodent taxa have been sighted with vER from 0.24 for the Striped Ground Squirrel *Xerus erythropus* to 0.04 for the Savannah Cane Rat *Thryonomys swinderianus* and the Giant Pouched Rat *Cericetomys gambianus*.

Encounters with indirect signs confirmed the presence of 14 other taxa (three Primates, two Carnivora, one Pholidota, one Hyracoides, one Rodentia, six Artiodactyla). Those taxa included four threatened taxa: the Western Chimpanzee *Pan troglodytes verus* (CR) (Humle et al. 2016), the Pygmy Hippopotamus *Choeropsis liberiensis* (EN) (Ransom et al. 2015), the Bosman's Potto *Perodicticus potto potto* (VU) (Svensson et al. in press), and the Black-bellied Pangolin (VU) (Waterman et al. 2014b) with sER of 0.51, 0.04, 0.08, 0.04, respectively (Table 1). The most frequently encountered signs were those of the Red River Hog at 1.73 sign/km, and the Bushbuck at 0.63 sign/km, respectively. Although the chimpanzee was not sighted, its presence was verified by its arboreal night nests and remains of partially-eaten fruits (their tooth marks are markedly different from other primates). Night nests were the most commonly found signs of the chimpanzee. Eight nests were observed that produced 0.31 nest/km. All the nests were in stage III, which indicates that all the leaves of the nest became dry, but the structure was still intact. Chimpanzee signs were most frequently encountered in the gallery forest along river Dodo (Fig. 3). We found 16 empty shotgun cartridges (0.63 sign/km) in the forest during recce walks. Outside surveys, the chimpanzee vocalization was mostly heard while they were raiding crops in cocoa and banana plantations.

Diversity of mammalian taxa obtained by remote cameras

Remote cameras captured the images of three mammalian taxa: Red River Hog *Potamochoerus porcus*, African Buffalo *Syncerus caffer*, and Bushbuck *Tragelaphus scriptus*, which were detected by indirect signs during surveys. For each species an image of individuals obtained from camera traps is provided: *P. porcus* (Image 1); *S. caffer* (Image 2) and *T. scriptus* (Image 3). The image capture rates (ICR) of these taxa were 0.044 for both *S. caffer* and *P. porcus*, and 0.024 for *T. scriptus* (Table 1).

Interview results

Table 1 also shows the result of interviews. Interviewees indicated that three additional taxa, Sooty Mangabey *Cercocebus atys*, the African Leopard *Panthera pardus pardus*, and the Black Duiker *Cephalophus niger*, although rarely, occurred at the DCF. Neither recce surveys nor remote cameras, however, confirmed their presence. Interviewees stated that they most often hunt animals when they raid the cocoa, coconuts, and other crops in the plantations, farms, and at the beach.

The locations of animal sightings and signs in and near the gallery forest

Thirty seven out of 50 (74.0%) animal sightings and signs occurred at less than one km from river Dodo. In particular, 95.8% of the sightings and signs of the primates occurred within this range (Figss. 3, 4). The mean distance (*d*) from river Dodo to the sighting locations and signs of the chimpanzee was 585.3m (range = 0–3,591.2m, sd = 998.2m) while *d* for other

Table 1. Mammalian taxa and parameters obtained through surveys, interviews, and remote cameras.

Order	Taxon	Common name	Local name (Kroumen)	Interview result	vER (freq./ km)	sER (sign/ km)	Type of signs	ICR	IUCN Red List current status
Primates	*Pan troglodytes verus* (Blumenbach, 1799)	Western Chimpanzee	Wê	Common	0	0.51	FO, nest	-	CR
Primates	*Perodicticus potto potto* (P.L.S. Müller, 1766)	Bosman's Potto	Tonroutchitchê	Common	0	0.08	VOC	-	VU
Primates	*Galagoides demidoff* (G. Fischer, 1806)	Demidoff's Dwarf Galago	Nenomiagnié	Common	0	0.08	VOC	-	LC
Primates	*Cercopithecus lowei* (Thomas, 1923)	Lowe's Monkey	Toiyourrô	Common	0.04	0.24	VOC	-	VU
Primates	*Procolobus verus* (Van Beneden, 1838)	Olive Colobus	Tawahou	Common	0.12	0		-	VU
Primates	*Cercocebus atys* (Audebert, 1797)	Sooty Mangabey	Kéré	Rare	0	0	N/A	-	EN
Primates	*Colobus polykomos* (E.A.W. Zimmermann, 1780)	King Colobus	Blôho	Common	0.04	0	N/A	-	EN
Primates	*Cercopithecus petaurista petaurista* (Schreber, 1774)	Eastern Spot-nosed Monkey	Djibetoua	Common	0.12	0	N/A	-	LC
Carnivora	*Civettictis civetta* (Schreber, 1776)	African Civet	Boué	Common	0	0.12	FM, FP	-	LC
Carnivora	*Crossarchus obscurus* (Cuvier, 1825)	Common Kusimanse	Hanlan	Common	0.12	0.16	FP	-	LC
Carnivora	*Lutra maculicollis* (Lichtenstein, 1835)	Spot-necked Otter	passô	Common	0	0.12	FM, FP	-	NT
Carnivora	*Panthera pardus pardus* (Linnaeus, 1758)	African Leopard	Dji	Rare	0	0	N/A	-	VU
Pholidotes	*Phataginus tetradactyla* (Linnaeus, 1766)	Black-bellied Pangolin	Houê	Rare	0	0.04	FP, RS	-	VU
Pholidotes	*Phataginus tricuspis* (Rafinesque, 1821)	White-bellied Pangolin	Hêbegnant	Common	0.04	0	N/A	-	VU
Hyracoides	*Dendrohyrax dorsalis* (Fraser, 1855)	Tree Hyrax	Wéya	Common	0	0.12	VOC	-	LC
Rodentia	*Atherurus africanus* (Gray, 1842)	Brush-tailed Porcupine	Clo	Common	0	0.12	FM, FP	-	LC
Rodentia	*Cricetomys gambianus* (Waterhouse, 1840)	Giant Pouched Rat	Tahouadou	Common	0.04	0.04	VOC	-	LC
Rodentia	*Thryonomys swinderianus* (Temminck, 1827)	Savannah Cane Rat	Gbian	Common	0.04	0	VOC	-	LC
Rodentia	*Xerus erythropus* (Desmarest, 1817)	Striped Ground Squirrel	Kélétcha	Common	0.24	0.08	VOC, FO	-	LC
Artiodactyla	*Choeropsis liberiensis* (Morton, 1849)	Pygmy Hippopotamus	Nonwê	Rare	0	0.04	RS	-	EN
Artiodactyla	*Tragelaphus scriptus* (Pallas, 1766)	Bushbuck	Lidjonhon	Common	0	0.63	FM, FP	0.022	LC
Artiodactyla	*Philantomba maxwellii* (C.H. Smith, 1827)	Maxwell's Duiker	Kouêlê	Common	0	0.12	FP	-	LC
Artiodactyla	*Cephalophus niger* (Gray, 1846)	Black Duiker	Liro	Common	0	0	N/A	-	LC
Artiodactyla	*Hyemoschus aquaticus* (Ogilby, 1841)	Water Chevrotain	Gnioklê	Common	0	0.04	FP	-	LC
Artiodactyla	*Syncerus caffer nanus* (Sparrman, 1779)	African Buffalo	Toué	Common	0	0.31	FM, FP	0.044	LC
Artiodactyla	*Potamochoerus porcus* (Linnaeus, 1758)	Red River Hog	Bôyou	Common	0	1.73	FM, FP	0.044	LC

Abbreviations: vER - visual encounter rate | sER - sign encounter rate | CR - Critically Endangered | EN - Endangered| VU - Vulnerable | NT - Near Threatened | LC - Least Concern | VOC - Vocalization | FM - fecal matter | FP - footprints | FO - food remains | nest - sleeping nest | RS - Resting site | ICR - Image Capture Rate.

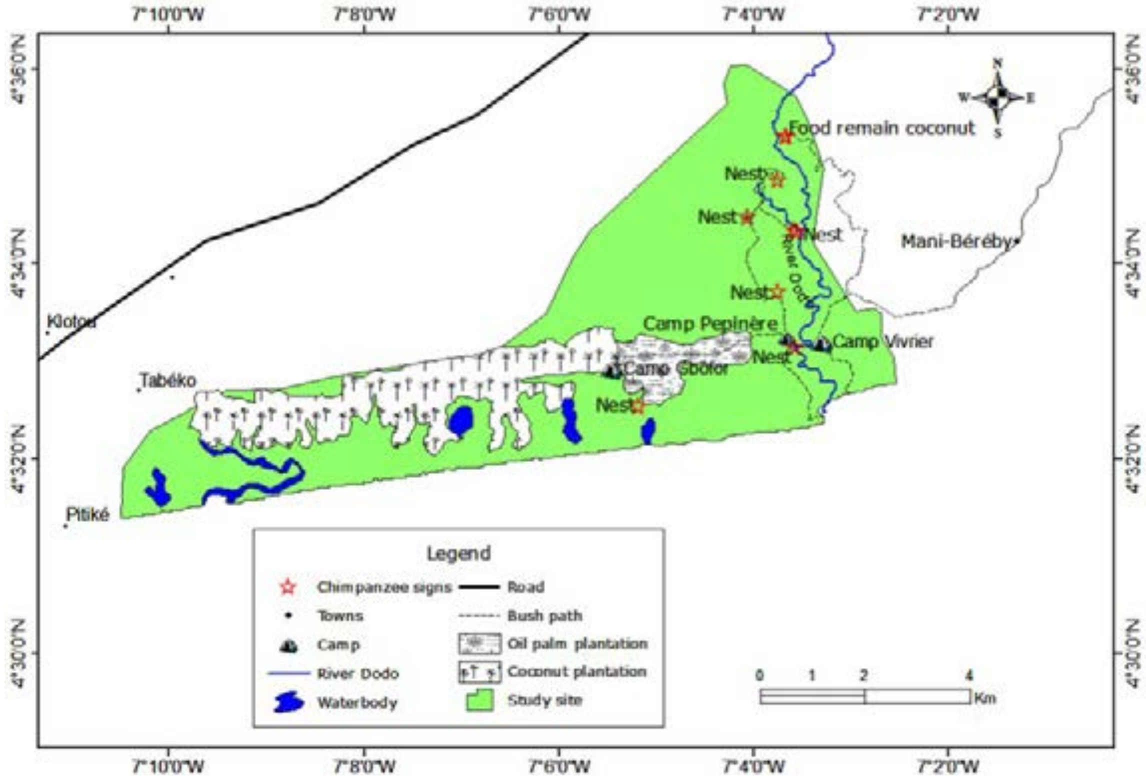

Figure 3. The locations of Chimpanzee signs.

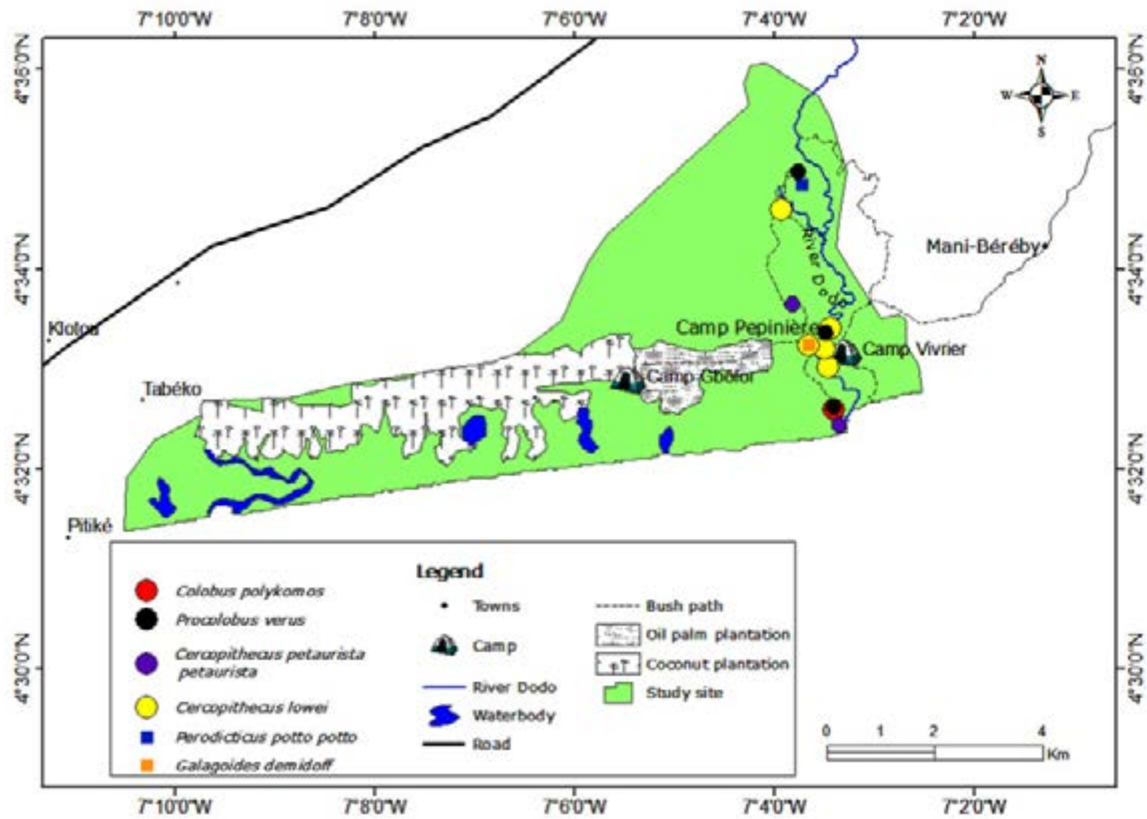

Figure 4. The locations of other primate sightings and their signs.

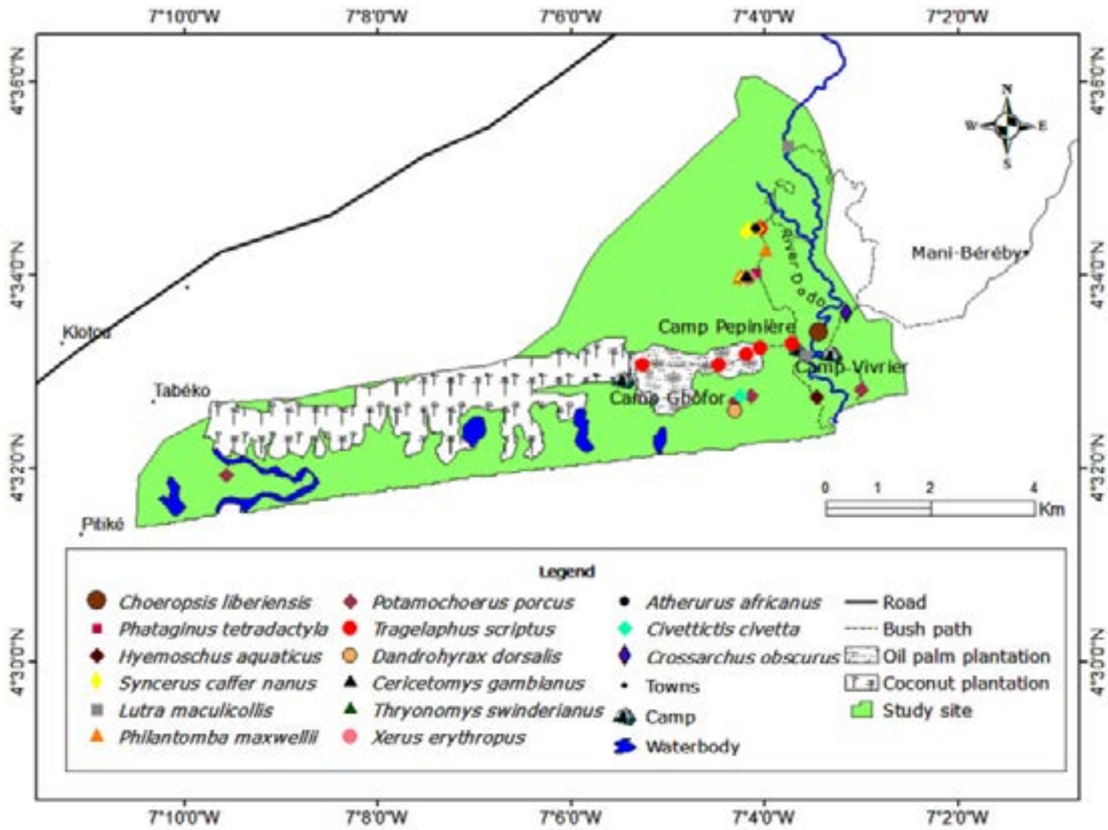

Figure 5. The locations of non-primate mammal sightings and their signs.

primates was 241.3m (range = 0–825.1m, sd = 264.5m), but the difference was not significant (t = -1.154, df = 12.538, p = 0.271) (Fig. 6). In contrast, more than 25.0% of the signs of non-primate mammals (NPM) occurred farther away from the river (Fig. 5). The d for non-human primates (NHP) (d = 413.3m, range = 0–3,591.2m, sd = 735.4) was significantly shorter (t = -2.3233, df = 30.873, p = 0.027) than that of non-primate mammals (NPM) (d = 1,479.1m, range = 0–11,678.1m, sd = 2,210.3m) (Fig. 6). Removing the outliers did not change this outcome (d for other primates = 188.2 m; d for the Chimpanzee = 312.1m; d for NPM = 1,071.1m).

DISCUSSION AND CONCLUSION

Our study at DCF in southwestern Côte d'Ivoire has confirmed the presence of 23 non-volant mammalian taxa including nine threatened taxa. One of them is Critically Endangered, the Western Chimpanzee and two Endangered, and the King Colobus and the Pygmy Hippopotamus.

The confirmed presence of the Western Chimpanzee and the King Colobus testifies to the need for targeted conservation actions at this forest. Indeed, the chimpanzee has become extirpated from a number of protected areas in Côte d'Ivoire. Viable populations of the ape are now restricted to a handful of national parks and reserves (Campbell et al. 2008). Even in these protected areas, the number of nests has recently become extremely low (Kühl et al. 2017). Surprisingly, sER (0.51) of the chimpanzee at the DCF was higher than that observed in the peripheral areas of Taï National Park (sER = 0.30). The high ER of the chimpanzee at DCF may be because the number of chimpanzees has been always high due to the local taboo against hunting the apes. Or it may be that the Leopard, described by Boesch (1991) a primary predator of the chimpanzee, has been extirpated from our study site.

As for *C. polykomos*, the combined effects of hunting and deforestation have led to the local extirpation of this species in many protected areas in Côte d'Ivoire (Gonedelé Bi et al. 2014; Bitty et al. 2015). Even though vER of the King Colobus was low, the presence of this species in the DCF is good news for the species.

Although legally prohibited in Côte d'Ivoire since 1974 (Caspary & Momo 1998), commercial hunting, is a common practice throughout the villages bordering this

Image 1. Individual of the Red River Hog *Potamochoerus porcus* captured by a camera traps at Dodo Coastal Forest.

Image 2. Individuals of the African Buffalo *Syncerus caffer* captured by camera traps at Dodo Coastal Forest.

Image 3. Individual of the Bushbuck *Tragelaphus scriptus* captured by camera traps at Dodo Coastal Forest.

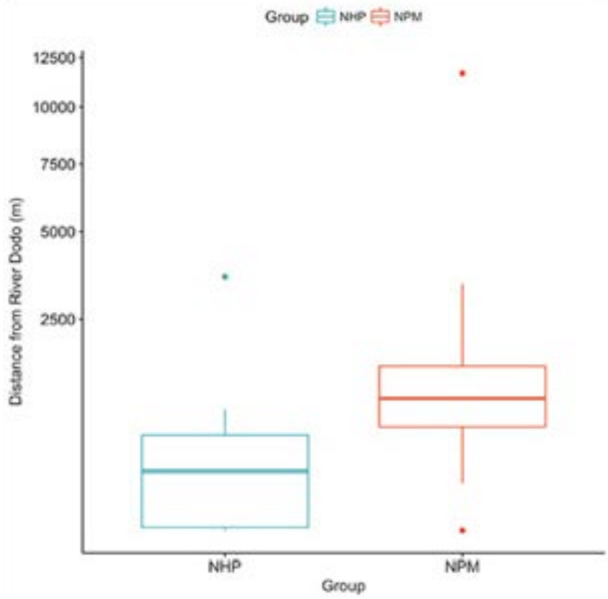

Figure 6. The mean distance (d) from the river Dodo to the sightings and signs of non-human primates (NHP) (d= 413.3, range =0–3591.2m, sd = 735.41) was significantly shorter (t = -2.3233, df = 30.873, p = 0.02692) than that of non-primate mammals (NPM) (d=1479.1m, range = 0–11,678.1m, sd = 2,210.3m). The difference between the chimpanzee sign distance (d=585.3m, range = 0–3591.2m, sd = 998.2m) and that of other primates (d =241.3m, range = 0–825.1m, sd = 264.5m) was not significant (t = -1.154, df = 12.538, p = 0.27).

coastal forest. In the DCF, however, the villagers mostly hunt mammals for their local consumption. Fortunately, commercial bushmeat trade is not a large part of the village economy. Still, we found a high level of hunting signs in the forest. During the surveys, the observed signs of hunting occurred in the gallery forest. Poaching appears to be the most serious threat to all the primates in our study site.

The fact that most sightings and signs of primates occurred in and near the gallery forest indicates the importance of the riverine ecosystem to the primate community. The most common tree species (e.g., *Parinari excelsa* (Chrysobalanaceae); *Sacoglottis gabonensis* (Humiriaceae); *Panda oleosa* (Pandaceae); *Klainedoxa gabonensis* (Irvingiaceae)) and large lianas (e.g., *Saba senegalensis* (Apocynaceae)) found in the gallery forest provide important foods for the primates. In fact, gallery forests are often the last refuges for threatened primates and have the potential to act as corridors (Bermejo 1999; Mbora & Meikle 2004; Gautier-Hion & Brugière 2005; Lees & Peres 2008; Shanee et al. 2013). Protecting, expanding, and improving the health of the gallery forest is one of the best ways to safeguard the threatened primates of DCF.

We found that DCF is also home to the Pygmy Hippopotamus, a locally and globally Endangered species. Given the declining trend of the population size of this species at the rate of 20% over two generations (26 years), and its small total population size (about 4000 individuals), the presence of the species here gives us hope (Mallon et al. 2011, FFI and FDA 2013; Ransom et al. 2015). A study at Gola National Forest and Gola Rainforest National Park in Sierra Leone and Liberia found that the most suitable habitat for this species was in community-owned landscape with a high density of the herbaceous plant, *Triumfetta cordifolia* (Tiliaceae) rather than in protected areas (Hillers et al. 2017). *T. cordifolia* is relatively abundant in the DCF wetland and since international concern for the Pygmy Hippopotamus has recently increased in the last decade or so (Conway et al. 2015), DCF has potential to attract tourists using the Pygmy Hippopotamus as an umbrella species (and primates). Revenue from tourism can have a significant positive effect if such a program is carefully planned to prevent pathogen transmission and other negative effects (Muehlenbein & Wallis 2014; Wright et al. 2014).

The current threatened status of the two African Pangolin species that occur in the DCF is Vulnerable. In contrast, the Asian pangolins (genus *Manis*) categorized as Critically Endangered and are among the most threatened species (Heinrich et al. 2016). Although we lack quantifiable data from West Africa, an estimate from Central African forests show that 0.4–2.7 million pangolins per annum have been hunted and the number of pangolins hunted has increased by 150% in the last 40 years (Ingram et al. 2018). Similarly, pangolins have become sought-after species in markets in Côte d'Ivoire and elsewhere in West Africa (Boakye et al. 2015; Challender et al. 2015). The pangolins recorded in DCF were extremely difficult to observe. Because population and behavioral-ecology data are lacking for these species, there is a need for a thorough study throughout their distribution ranges (Sodeinde & Adedipe 1994; Ingram et al. 2018).

Although almost all, if not all, mammalian populations that occur in the DCF are negatively influenced by anthropogenic disturbances (farming, hunting, timber extraction, mining, etc.) each taxon appears to have a different level of vulnerabilities to different factors. The Sooty Mangabey, the African Leopard, and the Black Duiker appear to have been extirpated from the DCF, but each of these taxa might have different primary causal factors for their demise (Nzooh et al. 2003). The Sooty Mangabey is a large-bodied semi-terrestrial primate that forages fallen fruits, ranging in a large social group (McGraw et al. 2014). Their noise attracts the attention of hunters and trapping them by wire snares can easily decimate a small population. Thus, this species was probably extirpated primarily due to trapping and hunting. Meanwhile, the Black Duiker is a solitary forager that forages for fallen fruits. This species is larger in body size with a narrower ecological niche, requiring a larger area, than Maxwell's Duiker, which is a generalist forager (Hofmann & Roth 2003). As a result, it is possible that hunting and trapping and forest reduction equally contributed to the local extirpation of this species. The leopard is also a solitary diurnal predator that requires a large area to hunt prey animals (Jenny & Zuberbühler 2005), but villagers are afraid of them and do not hunt them. But forest reduction and poaching that has reduced prey densities might have been the primary causal factors of their extirpation from DCF.

This study confirmed five even-toed ungulate taxa (Red River Hog, bushbuck, African Buffalo, Maxwell's Duiker, Water Chevrotain *Hyemoschus aquaticus*). The signs of their presence were the most frequently found mammalian signs in this forest. Again, the fact that moderate densities of these taxa occur here may be attributed to an ecological release that has occurred after the extirpation of the leopard from the area (Brashares et al. 2010).

Evaluating mammalian diversity based on a direct comparison of ICR of remote cameras in different forests is controversial, because variations in the methods (e.g., height of the cameras, duration of image capture, the angle of the lens) may significantly influence the outcome (Kelly & Holub 2008; Cove et al. 2013). Our ICRs (0.022, 0.044) were much lower in comparison with 0.125 ICR obtained by a study conducted at the former Haute Dodo CF (Sanderson et al. 2005). Only by conducting a longer study deploying a greater number of cameras we can verify whether our low ICR is due to the short duration of each session at each location or a reflection of the low mammalian diversity.

Some protected areas are now failing to secure the future of several endangered wildlife (Campbell et al. 2008; Beresford et al. 2011; Matsuda Goodwin et al. 2017b; Kühl et al. 2017). As a result, community forests are becoming more and more important for wildlife conservation. The fact that the DCF contains nine threatened taxa gives us optimism that this forest may be able to act as an ecological source for the nearest protected areas if they are rehabilitated, increasing the linkage and connectivity to larger forests (Bennett 1998).

Endowed with threatened taxa, DCF is one of the most important community forests for biodiversity conservation in southwestern Côte d'Ivoire. As stated above, DCF also has a potential to be developed as an ecotourism site with a stretch of an attractive beach and the forest and wetland that boasts of enigmatic mammals. We recommend that the local authorities urgently take actions to protect DCF. Conservation measures should involve enhancing law enforcement against poaching and installing a surveillance program. Law enforcement against charcoal production also needs to be improved. Currently, charcoal production sites exist close to the dense rainforest and hunters use the sites as camps within the forest. If charcoal producers and hunters are given alternative means, even partially, to earn their living (e.g., working as eco-guides), such activities could be substantially reduced. Furthermore, a conservation education program targeting the villagers and students will allow a better understanding of the importance of the forest and the ecological services that animals provide for the regeneration of the forest.

The confirmed presence of a number of emblematic taxa in the DCF instills hope for the conservation of its biodiversity. Global demand for oil palm, coffee, and cocoa, however, continues to push the region's industrial-scale agriculturalists to exploit the remaining forests. We reiterate that maintaining and rehabilitating the healthy ecosystem, especially along river Dodo, and creating a tourism-centered reserve at DCF will ensure its long-term effective protection.

This preliminary study was limited in scope and it is likely that many taxa were missed. For example, our study did not record any Insectivora or Lagomorpha species. Nevertheless, this paper has demonstrated that the community forests like the DCF may harbor a higher diversity of fauna than nearby "protected areas" that have gone through much destruction and deserve conservation resources. More thorough research, with surveys over a longer duration of time and a greater number of cameras, is required to more accurately assess mammalian diversity. Research on Chiroptera is also needed to better understand the full diversity of wildlife in this forest.

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Threatened Taxa

Résumé: Pour mieux connaître la diversité des mammifères non volants et comprendre les perspectives de conservation dans la Forêt Côtière de la Dodo (DCF) au sud-ouest de la Côte d'Ivoire, nous avons mené des enquêtes, des prospections puis examiné des images de pièges photographiques. Après avoir calculé les taux de rencontres visuelles (vER), les signes de présence (sER) des taxons de mammifères et les signes de chasse, nous avons cartographié leur emplacement et testé l'hypothèse selon laquelle les observations des signes de primates sont élevés près de la Dodo, à l'intérieur et près de la forêt galerie comparé aux autres taxons. Nous avons observé neuf taxons dont ces taxons menacés : le Colobe Magistrat (CR), le Colobe vert (VU), le Cercopithèque de Lowe (VU), le Cercopithèque blanc-nez (VU) et le pangolin à petites écailles (VU) dont les vER sont respectivement de 0,04; 0,12; 0,04; 0,12 et 0,04. Nous avons confirmé 14 autres taxons avec des signes incluant ces taxons menacés: le Chimpanzé d'Afrique de l'Ouest (CR), l'Hippopotame nain (EN), le Pottos de Bosman (VU) et le pangolin à longue queue (VU), avec un sER de 0,51; 0,04; 0,08 et 0,04 respectivement. 23 taxons ont été confirmés dans la DCF. La distance moyenne entre la rivière Dodo et les observations des primates était plus courte que celle des autres taxons. La chasse intensive avec 0,63 indice/km menace les mammifères de la DCF. Les images des pièges photographiques sont le Guib harnaché, le Buffle d'Afrique et le Potamochère roux à des taux de capture de 0,022; 0,044 et 0,044, respectivement. Nous recommandons aux autorités de prendre des mesures contre le braconnage, de réduire la production de charbon de bois et d'instaurer un programme de surveillance pour assurer la conservation des mammifères menacés de la DCF.

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COMMUNICATION

Resource selection by Javan Slow Loris *Nycticebus javanicus* E. Geoffroy, 1812 (Mammalia: Primates: Lorisidae) in a lowland fragmented forest in Central Java, Indonesia

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Abstract: Habitat loss and forest fragmentation have negative impacts on Javan Slow Loris *Nycticebus javanicus*, a Critically Endangered nocturnal primate endemic to Java. Reports confirmed that less than 9% of forest area remains on Java Island. One of the remaining natural habitats of the Javan Slow Loris is the fragment of Kemuning Forest in Temanggung Regency, Central Java. The purpose of this study was to determine resource selection and habitat variables that determine the presence of Javan Slow Loris. Habitat variables measured were basal area, tree connectivity, crown coverage on tree stage, slope, elevation, and distance to river. Data analysis performed was logistic regression, likelihood ratio test, and Akaike's Information Criterion with a backward elimination procedure. We also used direct observation and interviews with locals to collect data on environment and anthropogenic features of this forest. The results showed that the Javan Slow Loris uses resources selectively on a microhabitat scale. The habitat factors that influence the probability of resource selection by the species are canopy cover and slope. Habitat characteristics preferred by the Javan Slow Loris in Kemuning Forest are secondary lowland tropical rainforest with dense canopy cover located on a steep slope with low level of habitat disturbances. Although this study uses a small sample size, the expectation is that the results can be used as preliminary information for the habitat and population management of Javan Slow Loris in Kemuning Forest to guide conservation efforts and design management strategies.

Keywords: Forest fragment, habitat characteristics, Kemuning Forest, logistic regression, microhabitat, resource selection, threatened taxa.

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Author contribution: MS, SP and MAI conceived the idea; MS collected data; MS, SP, and MAI performed the analysis; SP led the writing; all authors contributed to the writing draft and approved the final version.

For **Bahasa Indonesia Abstract** see end of this article.

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INTRODUCTION

The Javan Slow Loris (Image 1) is a nocturnal, arboreal primate endemic to Java, Indonesia (Ross et al. 2014). It is categorized as a Critically Endangered species by the IUCN (Nekaris et al. 2013) and is protected by CITES under Appendix I, banning international trade for commercial purposes. This species is also included in the 25 most endangered primates in the world (Nekaris et al. 2008; Mittermeier et al. 2009; Voskamp et al. 2014; Schwitzer et al. 2017). In Indonesia, the Javan Slow Loris is highly protected under Law No. 5 of 1990 concerning Conservation of Natural Resources, and the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.20/ MENLHK/ SETJEN/ KUM.1/ 6/2018 dated 29 June 2018 on Types of Protected Plants and Animals.

Although the Javan Slow Loris has a wide range (Nekaris et al. 2008; Thorn et al. 2009) including human-dominated landscapes (Voskamp et al. 2014), habitat loss and forest fragmentation in Java has had a significant impact on the survival of this nocturnal species. Java is one of the most populated islands in the world, with 1,071 inhabitants per square kilometre (Rode-margono et al. 2014). It is subject to increasingly high rates of deforestation, habitat fragmentation, local extirpation of species (Chettri et al. 2018), and other impacts related to rapid population increase and industrialization. Research confirmed that less than 9% of forest area remains in this area. Most are montane forests, with only a very small amount of lowland forest remaining (Balen 1999; Reinhardt et al. 2016).

Among the remaining small fragments of lowland tropical forests, a small population of Javan Slow Loris can be found in Kemuning Forest of Central Java (Siregar 2014; Krisanti et al. 2017). Kemuning Forest is a part of a production forest area managed by the Indonesian State Forest Company (Perum Perhutani) of Kedu Utara Unit Management. Agroforestry shade-grown coffee plantations were implemented by Perum Perhutani with Collaborative Forest Management System (CBFM) in Kemuning Forest (Ahmad 2017; Krisanti et al. 2017). Currently, research of the Javan Slow Loris is limited to conservation areas (Nekaris 2014) and plantations or agroforestry areas (Wirdateti 2012; Nekaris et al. 2017). Research on the Javan Slow Loris in lowland tropical fragmented forests with the presence of shade-grown coffee plantation is still scarce.

Resource selection is an important factor for understanding the relationship between habitat and wildlife (Manly et al. 2002). Selection studies usually deal with food or habitat selection. There are two different categories of habitat selection, that among various discrete habitat categories (e.g., open field, forest, and rock outcropping) and that among a continuous array of habitat attributes (such as shrub density, percentage cover, distance to water, and canopy height; Manly et al. 2002). The resource selection model can be obtained by applying logistic regression analysis. The logistic regression method is suitable for analyzing the selection of several habitat variables and also dichotomous data in the form of the presence and absence of the Javan Slow Loris. A logistic regression analysis produces a resource selection function (RSF; Manly et al. 2002) and demonstrates the probability value of usage on each of the resource variables by wildlife (Weins et al. 2008).

Image 1. Javan Slow Loris *Nycticebus javanicus*

Primate species among arboreal mammals are commonly selected to assess the effects of habitat disturbance as they rely on primary forest habitats and also have primary functions as predators, seed dispersers (Kays & Alisson 2001), and ecosystem balance keepers (Basalamah et al. 2010). To understand how a nocturnal arboreal primate responds to habitat disturbance, especially in a lowland fragmented forest, we conducted research to determine the microhabitat factors that influence the presence of the Javan Slow Loris on a microhabitat level in Kemuning Forest. The main question asked in this research was whether the Javan Slow Loris performs resource selection at the microhabitat level in the lowland fragmented forest of Kemuning Forest. Therefore, our research hypotheses were 1) the Javan Slow Loris has its own habitat characteristics and performs resource selection at the

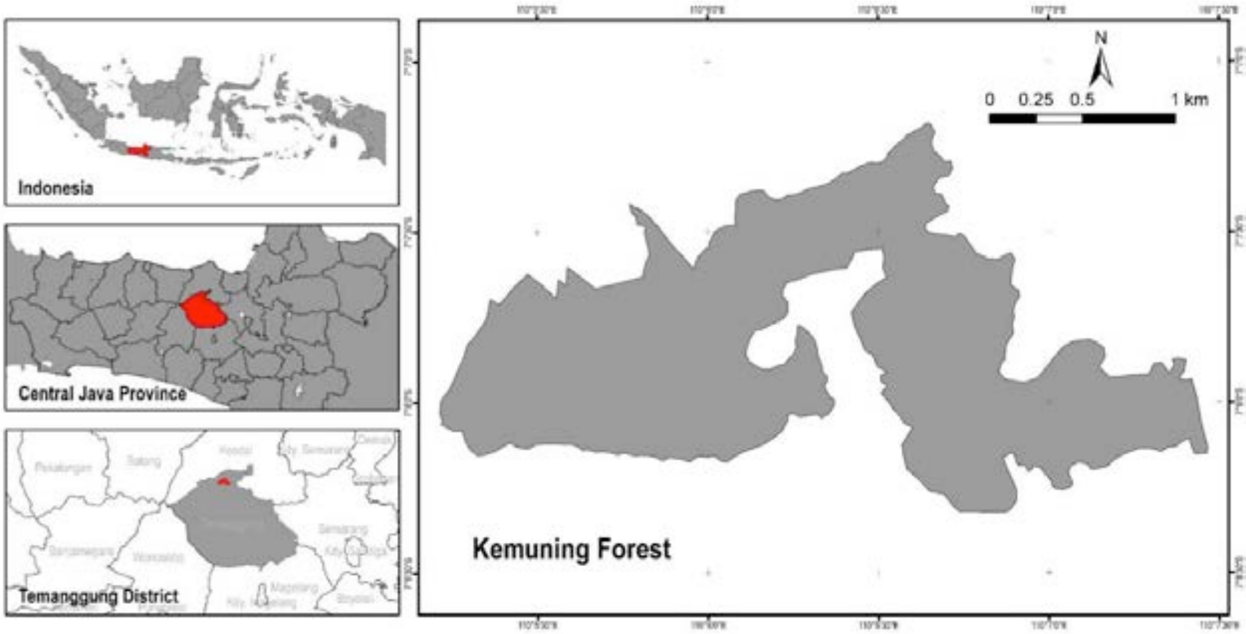

Figure 1. The study area in Kemuning Forest, Central Java, Indonesia.

microhabitat level in the lowland fragmented forest of Kemuning Forest and 2) environment factors influence resource selection by the Javan Slow Loris at the microhabitat level in the lowland fragmented forest of Kemuning Forest.

MATERIALS AND METHODS

Study Area

The research was conducted in the Kemuning Forest, Bejen District, Temanggung Regency, between February and October 2017. Geographically, Kemuning Forest is located at 110.086–110.124 BT & -7.119–-7.138 LS. Kemuning Forest, which has an area of approximately ±373ha (Fig. 1), is a part of a production forest area that functions especially for protected forests managed by the Indonesian State Forest Company (Perum Perhutani) of Kedu Utara Unit Management. There is an enclave village called Desa Kemuning within the forest area and most of the locals practice agroforestry management such as shade-grown coffee in the forest area. The agroforestry system is a collaborative scheme between Perum Perhutani and the Kemuning villagers.

According to the Schmidt-Ferguson classification system, this study area falls under wet climate (B climate classification (Sugiyanto 2017)) having characteristics with rainfall over the past nine years ranging from 2,176mm/yr to 4,649mm/yr. The average rainfall is 2,931mm/yr and monthly rainfall is 245mm/yr (Sugiyanto 2017). In general, topographic conditions in the study area are dominated by steep slope categories and this remaining tropical lowland forest has an altitude range between 300m and 600m.

Night surveys

We performed night surveys to detect the presence of the Javan Slow Loris in Kemuning Forest. Five repeated night surveys in 2017 were used as the main basis of data analysis. The night surveys were carried out using occupancy techniques (MacKenzie et al. 2002) by dividing the study area into 141 grids with the dimension of 200m x 200m (4ha) each. This grid size was adjusted to the size of the smallest home range of the slow loris in a disturbed natural forest, which is 2.8ha (Fig. 2; Wiens 2002; Nekaris et al. 2013). Vegetation types in the given area were recorded along the transects, as were any signs of disturbance or sources of threat to the Javan Slow Loris. Additionally, we also interviewed the local people to obtain information on the location of sightings of Javan Slow Loris, the management of the agroforestry system, and the threats that the species faces.

The night survey started at 18.00–19.00 h and finished at 23.30–03.00 h (Pliosungnoen et al. 2010). In general, the night survey was between 18.00h and 03.00 h. We are aware that the active time of the species is 18.00h to 06.00h (Nekaris 2003; Wiens & Zitzmann 2003); however, due to weather and physical conditions

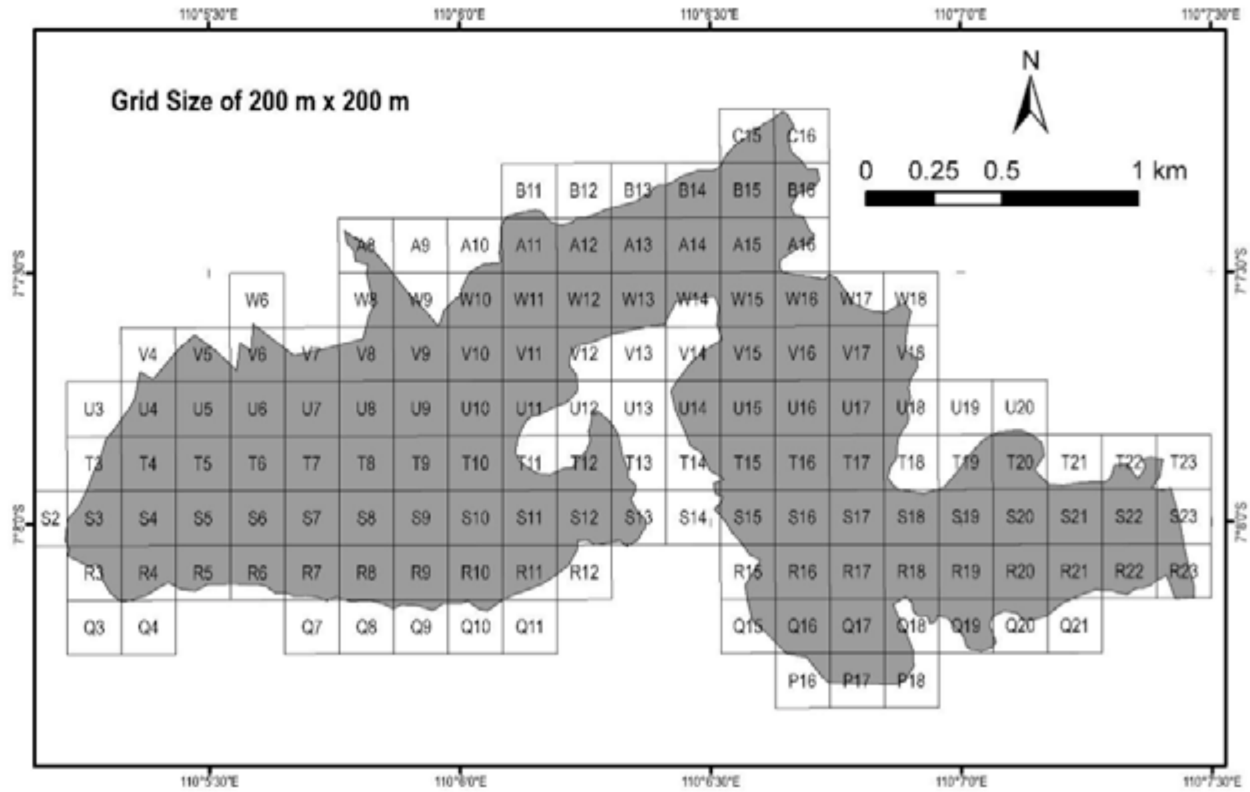

Figure 2. Grid size of 200m x 200m of the study area in Kemuning Forest, Central Java, Indonesia.

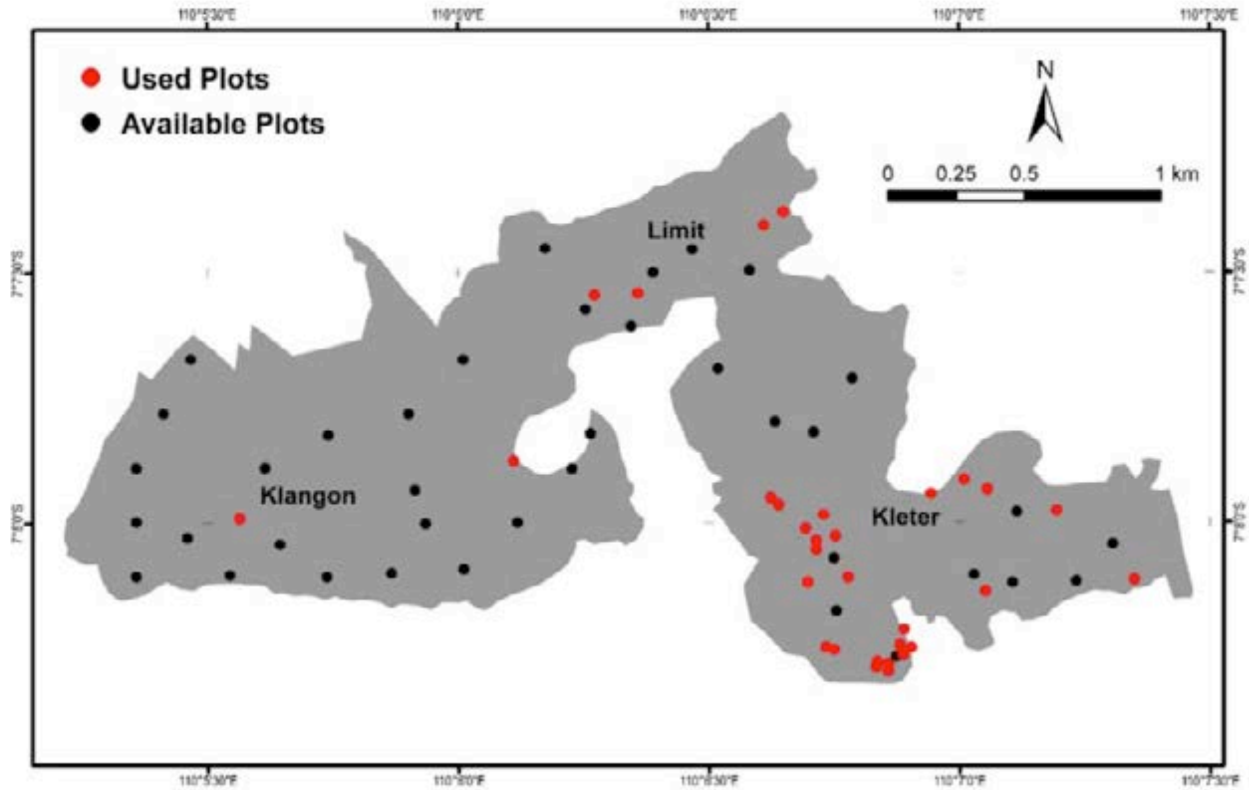

Figure 3. Used and available plots within the study area in Kemuning Forest, Central Java, Indonesia.

of observers, the observation occasionally had to finish earlier. We walked along the existing walking paths at a slow speed of maximum 800m/h (Nekaris et al. 2014) and stopped every 20m to conduct observations for 5–15 min. To distinguish the Javan Slow Loris from other nocturnal arboreal mammals, we used a yellow filter lamp. In order to reduce interference, however, a red filter lamp was utilized to observe individual slow lorises as suggested by Nekaris et al. (2008). The observation team consisted of only two people to minimize disturbance to the animals (one observer and one assistant; Nekaris 2003). If a Javan Slow Loris was spotted and identified during the night surveys, its location in the study area and time of night were noted. Each tree used by the slow loris was marked with flagging tape, with a different sign for each individual animal.

The following data was collected for each sighting: the number of individuals, height in tree, activity when first detected, tree species, and geographic coordinates (Nekaris et al. 2008). We collected microhabitat data used by the Javan Slow Loris from an available plot that was determined previously by random method as well as on the used plot (plot used by the Javan Slow Loris) determined in the field using a search sampling method (Morrison et al. 2001). The 20m x 20m (0.04ha) plot size was applied to measure the vegetation variables (Fig. 3).

The microhabitat variables measured in this study were biotic and abiotic components, i.e., the average of branch tree height (X_1), the average of tree height (X_2), basal area (X_3), tree connectivity (X_4), crown coverage on tree stage (X_5), slope (X_6), elevation (X_7), distance to road (X_8), distance to settlement (X_9), and distance to river (X_{10}).

The biotic variable measurement was calculated with nested sampling for vegetation measurements at tree level (DBH≥10cm; Pliosungnoen et al. 2010). The canopy cover measurement was calculated using a vertical tube (Johansson 1985; Morrison 2002). The slope was obtained using clinometers and the elevation was found using the feature on the GPS receiver. The measurement of the distance to river, settlement, and road was done using QGIS software. All measurements of trees and plots were conducted within the same season when the animal was observed (Pliosungnoen et al. 2010). Identification of plant species was carried out by herbarium collection, checking the local name, and through the database in the forestry faculty of Gadjah Mada University.

Analysis

We performed comparison analysis between used and available resources using T-Test for normal data, or Mann-Whitney U-test for non-normal data after the Shapiro-Wilks normality test. We carried out a multicollinearity test to all variables measured to see whether there is no high degree of multicollinearity among the independent variables indicated by variance inflation factor (VIF) value less than four (Pan & Jackson 2008; Hair et al. 2014). Any variable with a VIF value that exceeded four was excluded from the model.

To find out the microhabitat components that influence the probability of the presence of the Javan Slow Loris, a logistic regression analysis was performed following Manly et al. (2002). The selection of the best logistic regression models was based on the Akaike's information criterion (AIC). The best equation model was determined based on the smallest AIC value.

We applied a step-wise procedure from the logistic regression model with a backward elimination method. Therefore, habitat variables with the lowest significance value (*p*-value) were eliminated from the logistic regression model in stages. The result of the best model was tested with goodness of fit (Hosmer & Lemeshow 2000) and the differences between the models and the observation data were then tested with chi-square test (Hosmer & Lemeshow 2000). All statistical analysis was run with R 3.5.2 statistical data processing package.

RESULTS

Javan Slow Loris encounters at Kemuning Forest

We covered the entire area of Kemuning Forest while conducting five repeated surveys, in which we held 50 night surveys over the course of ±225.75h. We recorded 33 loris encounters (32 solitaries and one pair; Fig. 4). The distribution of the Javan Slow Loris in Kemuning Forest was clustered in three different locations: in Kleter with 26 individual encounters, in Klangon with two individual encounters, and Limit with five encounters. The Javan Slow Loris used 17 different tree species (Table 1 & 2). The most commonly used tree species by lorises in Kemuning Forest were *Sterculia oblongata* and *Aphananthe cuspidata* (Blume) Planch. The average tree height used by the Javan Slow Loris was 21.7m, while the average tree diameter used was 0.70m. The Javan Slow Loris was mostly found at an average height of 14.18m above the ground.

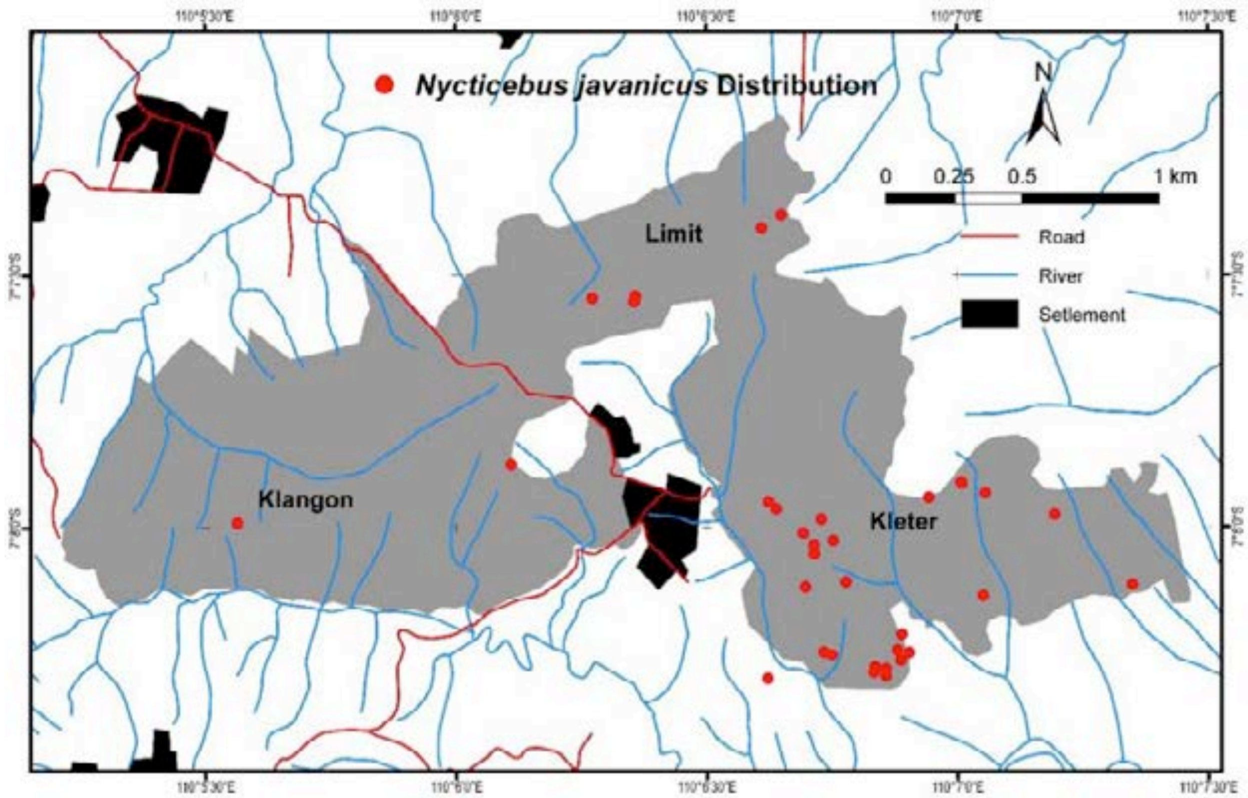

Figure 4. Javan Slow Loris encounter during night surveys in Kemuning Forest, Central Java, Indonesia.

Habitat characteristics at Kemuning Forest

Ten microhabitat variables in Kemuning forest obtained based on the result of the measurements of habitat characteristics (Table 3). There are four microhabitat variables that significantly influenced the presence of Javan Slow Loris in the study area: basal area, tree connectivity, crown coverage on tree stage, and slope (Table 4). The study area is dominated by a low basal area of trees with the value of 1000–3000 cm^2/ha. Some plots have a very high tree basal area value even with very low frequency (Fig. 5). There were significant differences between used plot and available plot (Mann-Whitney U-test (p=<0.05). The tree connection data in the study area was dominated by trees with the connectivity of 40–70 %, while trees with 100% connectivity were very small (Fig. 5). The result showed that used and available plots are significantly different (T-test, p=<0.01). The crown coverage in the study area was dominated by a dense canopy (Fig. 5). There was a significant difference between used and available plot of the crown coverage (Mann-Whitney U-test, p=<0.01). In general, the study area has a steep slope. The Mann-Whitney U-test result showed significant differences (p=<0.01) between used and available plots.

Resource selection by Javan Slow Loris in Kemuning Forest

The multicollinearity test resulted in six variables that are free from high degree of multicollinearity out of ten variables (Table 5). Those variables are basal area, tree connectivity, crown coverage on tree stage, slope, elevation, and distance to river. These six variables were further elaborated and analyzed.

The logistic regression analysis produced a deviation of 93.738 with 67 df for the model with predictors, while the deviation for the null model was 44.782 with 61 df. The difference in deviation was 48.956 with 6 df. The chi-square test result (p=<0.01) showed a significant difference, suggesting that there is at least one independent variable that affects the dependent variable. This shows that Javan Slow Loris performs a selection of certain resources to meet its needs.

There were two microhabitat variables (crown coverage β=0.1934±0.06528, and slope β= 0.114±0.04518) of the six variables tested which had a significant effect on the presence probability of Javan Slow Loris in the study area (Table 6). Four variables, however, did not significantly influence the presence probability of the species. The elimination procedure was performed in four stages to obtain the smallest

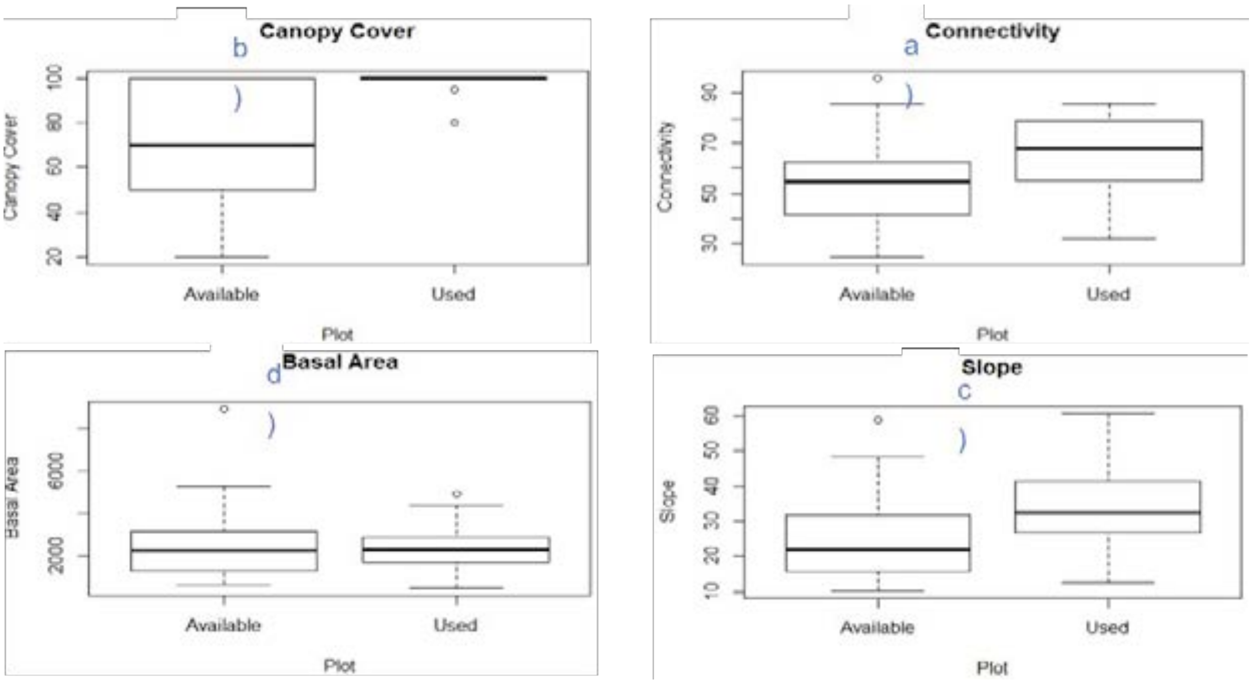

Figure 5. Comparison of distribution data between used and available plots in Kemuning Forest, Central Java, Indonesia: a) connectivity (%) | b - canopy cover (%) | c - slope (%) | d - basal area (cm^2/ha).

Table 1. Ethogram of the behaviour of Javan Slow Loris

Alert	: Resting but still observing the surroundings or the observer.
Feeding	: Eating food.
Foraging	: Movement related to foraging (including visual and olfactory searches that may have a social context but are difficult to describe).
Social	: Interaction, including attack behaviour, grooming, or other social behaviour.
Travelling	: Continuously moving, moving forward from one place to another.
Freeze	: Making a little movement, standing upright, or in a sitting position for at least 3s, moving very slowly but not related to foraging activities.
Sleep	: There is no movement, the head is between the knees, eyes closed.
Groom	: Licking or bathing itself, licking its body using its tongue or a tooth comb on its body.
Rest	: Staying upright, the head position between knees, eyes closed.
Other	: Other behaviours that are not specified on the ethogram.

AIC value. The gradually eliminated variables from the logistic regression model were basal area, tree connectivity, elevation, and distance to river. The smallest AIC value was obtained in the fourth stage with AIC=55.071. Therefore, the results of the best statistical model remain in two microhabitat variables which influence the presence of the Javan Slow Loris in Kemuning Forest (Table 7). The Hosmer & Lemeshow goodness of fit test for the best model yields *p*-value (0.65)>0.05, which indicates that the logistic regression model is quite good (fit) and acceptable. The coefficient of determination (R^2L) of the logistic regression on the best model was 49.14. The coefficient of determination (R^2L) value showed that the independent variable was able to predict the presence of Javan Slow Loris in the Kemuning Forest by 49.14%. The logistic regression model to predict the presence of Javan Slow Loris in Kemuning Forest is as follows:

$$\pi = \frac{\exp(-18.741 + 0{,}168X1 + 0{,}103X2)}{1 + \exp(-18.741 + 0{,}168X1 + 0{,}103X2)}$$

where π is the presence probability of Javan Slow Loris, X1 is the crown coverage on tree stage, and X2 is the slope.

Table 2. Trees species used by the Javan Slow Loris in Kemuning Forest, Central Java, Indonesia.

Tree species	Family	Height (m)	Tree DBH (m)	Tree height (m)	Activity
Blumea balsamifera Dc.	Asteraceae	7	0.7	17	Foraging
Spondias pinnata (L.f.) Kurz	Anacardiaceae	13–25	0.4–1.6	19–35	Traveling
Aphananthe cuspidata (Blume) Planch	Cannabaceae	9–20	0.5–0.8	17–29	Alert, traveling
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	12	0.6	19	Traveling
Dillenia obovata (Blume) Hoogland	Dilleniaceae	9	0.8	17	Traveling
Albizia chinensis Morr.	Fabaceae	6	0.4	12	Traveling, social
Vitex pubescens Vahl	Lamiaceae	15	0.7	21	Traveling
Litsea velutina (Blume) Hook.f	Lauraceae	7	0.7	27	Foraging
Litsea glutinosa (Lour.) C.B. Rob.	Lauraceae	10–12	0.4–0.6	17–18	Traveling, alert
Sterculia urceolata Sm.	Malvaceae	12–20	0.4–1.2	17–35	Traveling, feeding
Dysoxylum gaudichaudianum (Juss.) Miq.	Meliaceae	6	0.1	8	Traveling
Adenanthera microsperma T. & B.	Mimosaceae	15	0.8	20	Alert
Artocarpus elasticus Reinw ex. Blume	Moraceae	17–19	1.1–1.3	27–28	Alert
Ficus sundaica Blume	Moraceae	20	1.1	27	Traveling
Ficus superba Miq.	Moraceae	15	0.9	22	Traveling
Bamboo	Poaceae	14	-	15	Alert
Nauclea subdita (Korth.) Steud.	Rubiaceae	13–15	0.3–1.1	17–28	Alert, feeding
	Mean	14.18	0.70	21.76	
	Std. deviation	5.05	0.31	6.57	

Table 3. Recapitulation of the microhabitat variables of the Javan Slow Loris in Kemuning Forest, Central Java, Indonesia.

Variable	Used			Available		
	Mean	Min	Max	Mean	Min	Max
The average of branch free height (m)	8,25	4,4	12,7	8,45	3	15
The average of tree height (m)	17,2	10,8	23,8	18,04	11,6	27
Basal area (cm²/ha)	2397.35	488.9	4943.5	2608.91	629.7	8929.9
Tree connectivity (%)	65.02	32.1	85.7	53.91	25	95.8
Crown coverage on tree stage (%)	99.03	80	100	71.22	20	100
Slope (%)	33.33	12.5	60.5	24.4	10.2	58.7
Elevation (%)	547.15	468.2	629.5	563.28	454.1	625.2
Distance to road (m)	660,4	224,4	1654,8	513,3	10,1	1229,8
Distance to settlement (m)	706,87	251,0	1608,1	693,99	68,3	1517,2
Distance to river (m)	108.87	27.8	186.1	86.74	8.3	190.3

DISCUSSION

Based on the results of the night survey, the Javan Slow Loris encounters in the different heights on trees ranged from 6–25 m in Kemuning Forest. Munds et al. (2013) stated that slow lorises can be found from the ground to as high as 30+m. The Javan Slow Loris, as a species in the family Lorisinae, is known as a habitat-dependent species for the height of the used tree (Nekaris 2014). Therefore, the Javan Slow Loris can be found on varied soil surface height depending on the habitat conditions. The Javan Slow Loris uses *Sterculia oblongata* and *Aphananthe cuspidata* (Blume) Planch tree species more often than other species in Kemuning Forest since this species possibly has a suitable canopy cover for Javan Slow Loris. A dense tree canopy provides food and protection from predators and extreme temperature exposure to the Javan Slow Loris (Nekaris 2014).

Habitat characteristics at Kemuning Forest

The Kemuning Forest consists of natural forest vegetation that is disrupted by human interference, one of the activities of which is a coffee plantation under the forest stands (the shade-grown coffee). The coffee plantation system adopts an agroforestry system which is performed intensively in this area. The agroforestry system, however, changes largely the conditions of the forest. Farmers sometimes reduce canopy cover and understorey to increase the penetration of sunlight to the forest floor. These activities were done by cleaning shrubs and all tree saplings, resulting in increasing coffee productivity. This condition is in line with the coffee management in Latin America where farmers adopted 'sun systems' that utilize fewer shade trees (Perfecto et al. 1996). This practice is done by eliminating larger canopy tree species to promote air exchange and increase light penetration. This practice, however, presents a significant threat to the native flora and fauna in the forest (James 2014).

Based on observations and interviews with locals, it was found that farmers have continued to cut down the bamboo stands as those were disturbing the existence of coffee plantation within the study area. Besides expanding the coffee plantation area, the goal of cutting bamboo stands was to increase coffee productivity. Research carried out in Cipaganti, West Java, reported that bamboo stands are the dominant vegetation of sleep sites for Javan Slow Loris and function as substrates for feeding and avoiding ground movement (Nekaris et al. 2017). This practice, in general, affects the presence of Javan Slow Loris in Kemuning forest.

Moreover, the intensity of coffee management varies among farmers. It depends on the access (distance from the road), the land condition, and the wealthiness of each farmer. In the case where the coffee plantation is closer to the road, has better land conditions, or is overseen by a wealthier farmer, it typically results in management that is more intensive. This caused a variation within the microhabitat conditions of the forest, especially the canopy cover and the vegetation structure. A diverse canopy under shade-grown coffee management is an important habitat for biodiversity, but removing shade trees, limiting shade cover, and using agrochemicals generally result in losses of biodiversity for epiphytes, arthropods, birds, and mammals (Perfecto et al. 1996, 2007; Moguel & Toledo 1999; Philpott et al. 2007), especially slow loris.

Habitat characteristics of Javan Slow Loris in Kemuning Forest consist of forest area with dense canopy cover, small basal area, dominated by trees that are connected to each other and steep slope. Thus, forest structure plays an important role in the habitat selection of arboreal mammals (Datta & Goyal 1996). Tree connectivity is very important for Javan Slow Loris activities, as this animal cannot jump or leap. Nekaris (2019) stated that slow loris is a unique primate genus in terms of its inability to leap or jump and strong precise grip to hold onto branches. Slow lorises must rely on slow and steady climbing, hence the name. They manoeuvre across gaps using all levels of forest structure, including the ground (Nekaris 2019). Therefore, the existence of trees with continuous canopy is a useful habitat for the Javan Slow Loris (Munds et al. 2013). The suitability of tree connectivity conditions is important for the Javan Slow Loris in terms of safety, moving, and avoiding predators.

The Javan Slow Loris in Kemuning Forest tends to use a small basal area. The area in a small basal area in tree stage per plot usually consists of a small number of individual trees with a larger diameter. Mbora & Meikle (2004) found that the larger basal area is suitable for a group primate, while the Javan Slow Loris is known as a solitary animal. Like other arboreal primates, Javan Slow Loris tends to choose larger trees as these are related to higher food abundance (Vidal & Cintra 2006; Pliosungnoen et al. 2010). The Javan Slow Loris in Kemuning Forest tends to choose an area with dense canopy cover. The suitability of canopy cover conditions is very important for the animal's safety, to avoid air predators as well as walking on the ground (Garber 1992) and also to provide food and protection from extreme weather (Nekaris 2014). Bolen & Robinson (2003) argued that two essential elements of wildlife habitat are food and shelter/ cover. Food provides nutrients for body substances and energy for vital processes of wildlife, while shelter protects wildlife from extreme weather and predators. The tree canopies fulfil two basic habitat elements for the Javan Slow Loris population in the Kemuning Forest. In certain conditions, wildlife may ignore human threats in order to get their favourite food (Purnomo & Pudyatmoko 2011). As a canopy dweller species, the Javan Slow Loris requires dense canopy cover conditions for its activities (Pliosungnoen et al. 2010). Ray et al. (2012) argued that arboreal nocturnal mammals tend to choose habitats with tight canopy cover greater than 75%. The average canopy cover on the used plot in Kemuning Forest habitat was higher

Table 4. Habitat characteristics comparisons on used plot and available plot of Javan Slow Loris in Kemuning Forest, Central Java, Indonesia.

Habitat variables	Test type	*P* value
The average of branch free height (m)	T-test	n.s
The average of tree height (m)	T-test	n.s
Basal area (cm^2/ha)	Mann-Whitney U-test	<0.05*
Tree connectivity (%)	T-test	<0.01*
Crown coverage on tree stage (%)	Mann-Whitney U-test	<0.01*
Slope (%)	Mann-Whitney U-test	<0.01*
Elevation (%)	Mann-Whitney U-test	n.s
Distance to road (m)	Mann-Whitney U-test	n.s
Distance to settlement (m)	T-test	n.s
Distance to river (m)	Mann-Whitney U-test	n.s

Table 5. Result of the multicollenearity test of the variables.

Variable	Multicollinearity test (VIF value)		
	Before	After	
The average of tree height	8.28	-	Eliminated
Distance to settlement	5.50	-	Eliminated
The average of branch free height	5.02	-	Eliminated
Distance to road	4.43	-	Eliminated
Slope	3.84	2.03	
Elevation	3.20	1.66	
Basal area	3.14	1.60	
Crown coverage on tree stage	2.56	1.89	
Distance to river	2.26	1.33	
Tree connectivity	1.77	1.40	

Table 6. Estimated parameter results of the logistic regression model.

Variable	Estimate (β)	Standard error	Z value	Pr(>|z|)
intercept	-29.64	11.87	-2.498	0.01250*
Basal area	0.0000288	0.0003438	0.084	0.93316
Tree connectivity	0.01146	0.02658	0.431	0.66643
Crown coverage on tree stage	0.1934	0.06528	2.963	0.00305**
Slope	0.114	0.04518	2.531	0.0139*
Elevation	0.01139	0.0115	1.022	0.3067
Distance to river (m)	0.009646	0.0074	1.304	0.19239

* indicated significant difference with p values < 0.05
** indicated stronger significant difference with p values < 0.001

Table 7. RSF coefficient estimation of the best model with backward elimination method.

variables	β	Std. Error	Z value	Pr(>|z|)
Intercept	-18.74082	6.12146	-3.061	0.00220**
Crown coverage on tree stage (%)	0.16812	0.05833	2.882	0.00395**
Slope (%)	0.10261	0.03743	2.742	0.00611**

** indicated stronger significant difference with p values < 0.001

than 75%, though the available plot was slightly lower. This indicates that canopy cover condition in Kemuning Forest is still suitable for arboreal nocturnal mammals, especially the Javan Slow Loris.

Finally, alongside biotic factors, the presence of the Javan Slow Loris in Kemuning Forest is also influenced by abiotic factors. The slope is a part of the structural component that limits the quality of the habitat (Bailey 1984). Environment characteristics formed by slopes affect habitat quality. The Javan Slow Loris in Kemuning Forest tends to choose locations with steeper slopes as this allegedly relates to the activities of what farmers are cultivating on the land. The area with steep slopes tends to be less attractive for farmers to manage intensively. Research reported that steep slopes are one of the important management constraints due to mechanization difficulties and low soil fertility in agriculture areas with varied topography (Marini et al. 2009), and is characterized by high labour requirements (MacDonald et al. 2000). This means that the steep terrain gives less human disturbance pressure to the presence of Javan Slow Loris in the study area. In conclusion, the steep slope area in Kemuning Forest correlates with fewer disturbances by human activity since this area is categorized as having poor land condition by farmers for intensive coffee plantation.

Resource selection by the Javan Slow Loris in Kemuning Forest

Logistic regression result showed that the Javan Slow Loris in Kemuning Forest used microhabitat resources selectively. Habitat variables such as canopy cover and slope have influences on the presence of this species in Kemuning Forest. Therefore, these microhabitat variables in Kemuning Forest form a resource selection function for the presence of the Javan Slow Loris. Dense canopy cover becomes one of the essential limiting factors for the presence of Javan slow Loris in Kemuning Forest. Manly et al. (2002) stated that the main factor of resource selection by an animal is uneven resource distribution along the forest area. Therefore, the habitat variables used by the Javan Slow Loris vary within Kemuning Forest.

The comparison of habitat characteristics data between used and available plots showed significant differences on four variables. The result of logistic regression analysis, however, showed differences in which there were only two microhabitat variables that had a significant influence on the opportunity of resource selection function by the Javan Slow Loris in Kemuning Forest. Those variables are crown coverage on tree stage and slope. Canopy cover and slope contribute a significant effect on the opportunity of microhabitat selection as well as in the comparison of habitat characteristics data between used and available plots. The exp. (ß) value of canopy cover and slope mean that the higher the canopy coverage and the steeper slope, the higher the chance of probability of the presence of the Javan Slow Loris in the study area.

The limitation of this study is the small sample size of the presence data of the animal included in the data analysis. The slow loris is not only nocturnal but is also a small, cryptic, and arboreal species (Nekaris et al. 2014). Therefore, it is difficult to observe the presence of this animal and predict the numbers of the population. The locations within the study area where coffee plants are far from the road and settlement areas have a tendency to be less maintained. The detections of Javan Slow Loris were disrupted by the existence of these dense and irregular coffee plantations. A combination of night surveys and the use of camera traps installed in tree canopies are expected to increase the sample size of this study. In addition, observation of nocturnal animals such as the Javan Slow Loris requires certain skills where observers are used to conducting night survey activities. Ideally, in doing so, this increases the sample size and therefore results in a stronger model within this data analysis.

Despite the fact that this study presents a small sample size, it is capable of representing an overview of the microhabitat needs of the Javan Slow Loris population in Kemuning Forest. To maintain the sustainability of the species population in the area in the long term, it is essential to maintain the existence of vegetation with dense and connected canopy coverage characteristics within the forest. To maintain a suitable habitat, conservation efforts such as habitat management must be directed towards the locations that are truly favoured by the species, considering that the Kemuning Forest is a production forest surrounded by a non-natural forest area.

The results of this study indicate three key factors to improve conservation efforts and management strategies of the Javan Slow Loris. Firstly, the characteristics of Javan Slow Loris habitat in the Kemuning Forest are secondary lowland tropical rainforest with dense canopy cover, located in steep slopes, with low-level habitat disturbance. Secondly, the species exploits microhabitat resources selectively. Habitat factors that influence the probability of resource selection by the species are canopy cover and slope. Finally, canopy cover and slope have a strong influence on the presence of the species and formed a resource selection function in Kemuning Forest.

Therefore, in conclusion, to preserve the Javan Slow Loris population in the Kemuning Forest, it is important to maintain the existing vegetation with a dense canopy cover that is connected to each other. In addition, it is also important to maintain a low level of human disturbance and to manage how the human activities within Kemuning Forest area have the least impact on the presence of the Javan Slow Loris.

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Bahasa Indonesia Abstract: Faktor kehilangan/berkurangnya dan fragmentasi habitat yang terjadi di Pulau Jawa memberikan dampak negatif terhadap satwa endemik kukang Jawa (*Nycticebus javanicus*). Kukang Jawa adalah satwa primata nokturnal endemik di Pulau Jawa yang saat ini tergolong dalam kategori kritis. Hasil penelitian menunjukan bahwa kurang dari 9 % areal hutan alam yang masih tersisa di Pulau Jawa. Salah satu hutan dataran rendah yang tersisa adalah hutan Kemuning di Temanggung Jawa Tengah. Penelitian ini bertujuan untuk mengetahui seleksi habitat oleh kukang Jawa dan faktor-faktor habitat yang menentukan kehadirannya pada skala micro-site. Variabel habitat yang diukur adalah luas bidang dasar pohon, konektivitas pohon, penutupan tajuk pada tingkat pohon, kemiringan lahan, ketinggian tempat, dan jarak dari sungai. Analisis data yang digunakan adalah regresi logistik, likelihood ratio test, dan Akaike Information Criterion (AIC) dengan prosedur backward elimination. Kami juga melakukan observasi dan wawancara kepada masyarakat untuk mengumpulkan data tentang kondisi lingkungan dan gangguan akibat faktor keberadaan manusia. Hasil penelitian ini menunjukan bahwa kukang Jawa melakukan seleksi habitat pada skala mikro. Faktor habitat yang memengaruhi seleksi sumber daya oleh kukang Jawa adalah tutupan tajuk pohon, dan kemiringan lahan. Habitat karakteristik yang disukai oleh kukang Jawa di hutan Kemuning adalah hutan tropis dataran rendah dengan tutupan tajuk yang rapat dan berada pada kemiringan lahan yang curam dengan sedikit tingkat gangguan. Meskipun penelitian ini menggunakan ukuran sampel yang sedikit, diharapkan bahwa hasil dari penelitian ini dapat digunakan sebagai informasi awal untuk manajemen habitat dan manajemen populasi kukang Jawa di hutan Kemuning sebagai acuan dalam usaha-usaha konservasi dan desain strategi pengelolaan.

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Species composition and abundance of rodents in Kafta-Sheraro National Park, Ethiopia: preliminary results

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Abstract: An ecological survey was conducted to assess the species composition and abundance of rodents in Kafta-Sheraro National Park, Ethiopia from June 2017 to April 2018 covering wet and dry seasons. Rodents were trapped using Sherman live traps from five selected habitat types—natural forest, bushland, grassland, farmland, and human settlement. A total of 209 individuals of rodents belonging to seven species were captured over 2940 trap nights, and three species of rodents were only observed. The trapped rodent species include *Mastomys natalensis, Stenocephalemys albipes, Rattus rattus*, *Mastomys awashensis*, *Acomys cahirinus*, *Arvicanthis niloticus dembeensis*, and *Mastomys erythroleucus*. *Lemniscomys striatus, Hystrix cristata*, and *Xerus rutilus* were only sighted during the study. *Mastomys natalensis* was the most abundant species (41.1%), followed by *Stenocephalemys albipes* (26.3%) and *Rattus rattus* (18.2%), whereas *Mastomys erythroleucus* (1.4%) was the least abundant species. The abundance of female (59.8%) was higher than male (40.2%). Of the total trapped rodents, 52.2% were adults, 32% sub-adult and 15.8% young. The abundance of rodents was varied among habitat types and between seasons. The results of the study revealed that the park has diverse species of fauna including rodents.

Keywords: Diversity, Horn of Africa, Rodentia, Tigray Region.

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Author Contribution: AA conceived, designed and conducted the fieldwork. CS supervised the research. Both the authors wrote the manuscript.

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INTRODUCTION

Globally, rodents are the most diverse and abundant group of mammals. Over 32 extant families, 468 genera and 2,277 species of rodents are recognized throughout the world, which represents 42% of the mammalian species (Wilson & Reeder 2005; Wolff & Sherman 2007). Similarly, in eastern Africa rodents are the most abundant and numerous, which account for 28% of the total recognized species of mammals (Afework 1996; Kingdon 1997). Ethiopia is among the countries with a high resource of biodiversity and endemism due to its wide variation in altitude ranges, geographical positions and climatic conditions (Leykun 2000; Lavrenchenko et al. 2007). A total of 320 mammalian species were recorded in Ethiopia, of which 84 species are rodents with 21% endemic (Afework 1996; Lavrenchenko et al. 2007).

Rodents are successful mammals in every continent and able to exploit wide ranges of habitat types (Lange et al. 2004; Workneh et al. 2006). Habitat structure, disturbance, and other important environmental factors affect the distribution pattern and abundance of rodents (Tadesse & Afework 2008; Demeke & Afework 2014). The knowledge on global distribution and diversity of mammals are not complete, especially so for small mammals including rodents, insectivores, and bats, as many taxa are still being discovered (Kingdon 1997; Wilson & Reeder 2005). Many investigations were conducted to study the distribution and abundance of rodents in different parts of Ethiopia (Messele & Afework 2012; Adugnaw & Messele 2016). Many areas of the country, mainly the northern highlands and lowlands, are underexplored due to the remoteness, inaccessibility, harsh conditions, and political instability in protected areas such as Kafta-Sheraro National Park (KSNP), Dessa'a National Priority Forest Area and other local forests. KSNP is the newly established national park of the country and comprises diverse fauna and flora; however, scientifically its wildlife, particularly small mammal diversity including rodent community, is not entirely known. The present study aims to assess the species composition and abundance of rodents in the unexplored KSNP.

MATERIALS AND METHODS

Study area

The study was conducted in KSNP (14.055–14.464 ^{0}N & 36.695–37.675 ^{0}E), northern Ethiopia (Fig. 1). KSNP is located in the lowland part of western and northwestern Tigray regional state known for the highest peak of the country—Siemen Mountain, Ras Dashn. The altitudinal range of KSNP is between 568m and 1,163m with an average elevation of 870m. The national park was formerly established as Shire Wildlife Reserve area in 1968 and recognized as a national park in 2007 to safeguard the African Elephant and other biological resources. Initially the total area of the protected area was 5,000km^2 but currently, an area of 2,176.43km^2 has been accorded protected area recognition. The national park is bordered with three districts of the region; on the west is Kafta-Humera, on the east Tahtay-Adyabo, and on the south Welkayit. Eritrea borders the northern part of the national park. The agro-climate of the national park is identified with warmer temperature inclined to semi-arid climate. The national park is characterized by a uni-modal type of rainfall regime with one wet season and one dry season. It receives an annual average rainfall of 600mm, and high rainfall is during the wet season from the middle of May to the beginning of September. The average monthly temperature of the national park ranges from 18^{O}C to 37.5^{O}C. KSNP consists of spectacular topographic features that support diverse flora and fauna. The vegetation of the national park belongs to *Combretum-Terminalia, Acacia-Commiphora,* savanna grassland, and riparian woodlands type. KSNP is a host for 42 species of mammals, 200 species of birds, nine species of reptile, and various unstudied species of different animals and plants (Ethiopian Wildlife Conservation Authority 2015).

Grid design and trapping

Before the field survey, rodent collection permission was acquired from Ethiopian Wildlife Conservation Authority, Government of Ethiopia, and a preliminary survey was carried out to select study sites. Relevant information such as topography, climatic conditions, flora, fauna and others were gathered. Besides, habitat types of the park were identified based on the vegetation classification of the country (Yalden & Largen 1992) and five habitat types (Image 1), namely, natural forest, bushland, grassland, farmland, and human settlements, were selected for the study. A permanent live trapping grid was established at each of these five habitat types, and the trapping studies were conducted both during the wet and dry seasons. Each grid constituted an area of 4,900m^2 (70 x 70 m). A total of 49 Sherman live traps (7.6 x 8.9 x 22.9 cm) were set per each grid at 10m intervals between points. In each of the habitats studied, 49 traps were set for three consecutive days

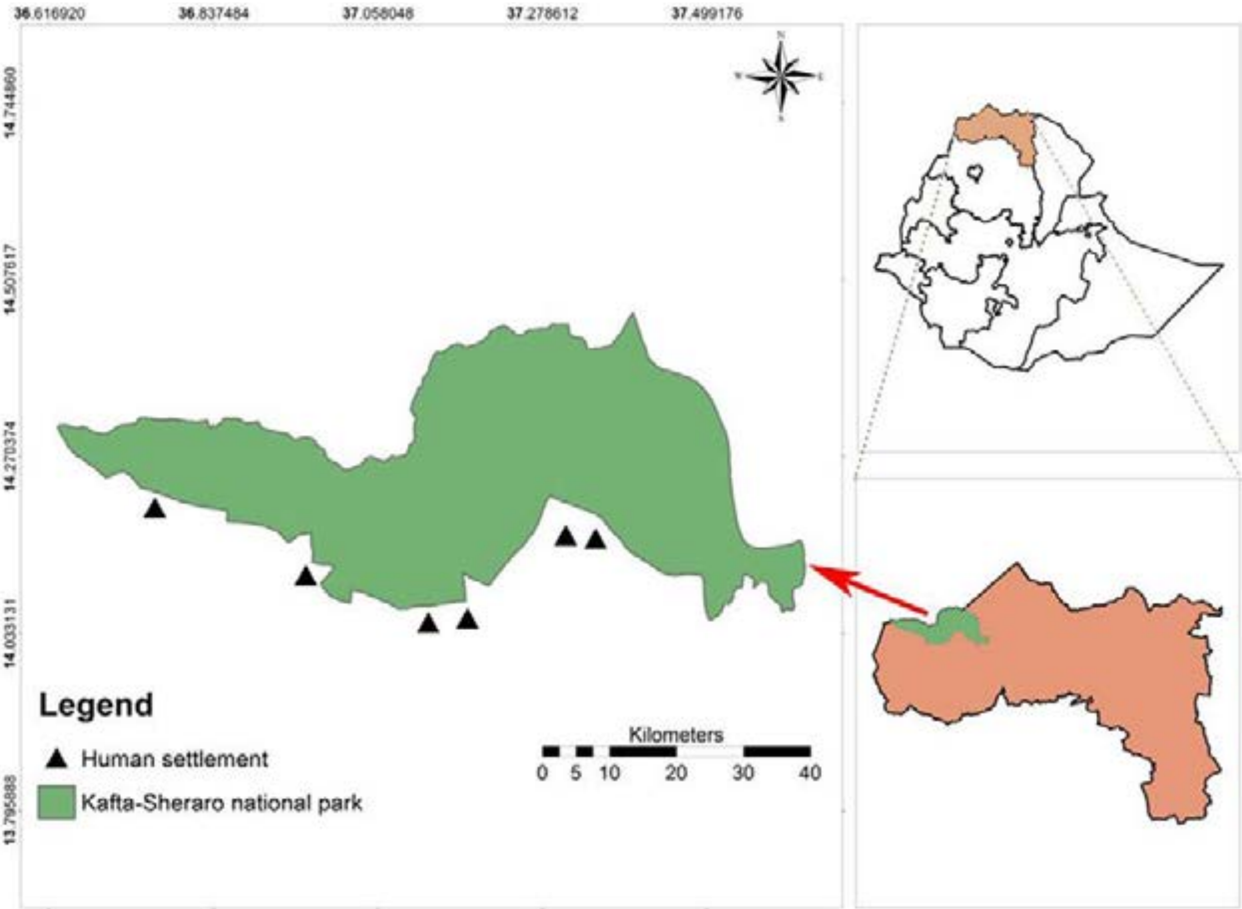

Figure 1. Kafta-Sheraro National Park (KSNP), Tigray Regional State, Ethiopia showing location of habitat types where rodent trappings were conducted.

amounting for 147 trap nights per habitat per season. During the present study 2,940 trap nights were spent in trapping efforts (147 trap nights x 2 seasons x 5 habitats). Peanut butter was mixed with crushed maize and rolled into small balls and then placed in the trap as bait. The traps were partially covered with leaves and grasses to prevent damage and death of trapped individuals. In order to locate the traps, each trap location was marked with yellow colored plastic tags on a branch of a nearby tree. Traps were checked early in the morning (07.00–09.00 h) and in the late afternoon (17.00–18.00 h) of each day for three consecutive days, and the bait was replenished as necessary to increase trapping success.

Each trapped rodent was collected and relevant data such as season, habitat type, station numbers, species type, body weight, sex, approximate age, and reproductive conditions were recorded. Sex of trapped rodents was determined based on their nipples, testes, and the distance between their anus and urethral opening. Their age was classified into three categories—juvenile, sub-adult, and adult—and was determined based on their body size and weight, pelage color, and reproductive conditions (Taylor & Green 1976; Afework 1996). Reproductive conditions were determined based on the opening of the vagina (imperforated or perforated), size of nipples, and body weight for females, and the position of testicles (scrotal/ abdominal testes) for males (Taylor & Green 1976). Furthermore, necessary information such as morphometric measurements including body weight, lengths of head and body, hind foot, ear, tail, and other morphological characteristics of each trapped rodents were recorded. Representative species were collected as vouchers, and the voucher specimens were deposited in the collection of the Zoological Science Natural History Museum of Addis Ababa University, Addis Ababa. All trapped rodents were marked by toe-clipping and released at their capture site for further capture-mark-recapture studies. Species identification was following standard references (Afework 1996; Kingdon 1997). The

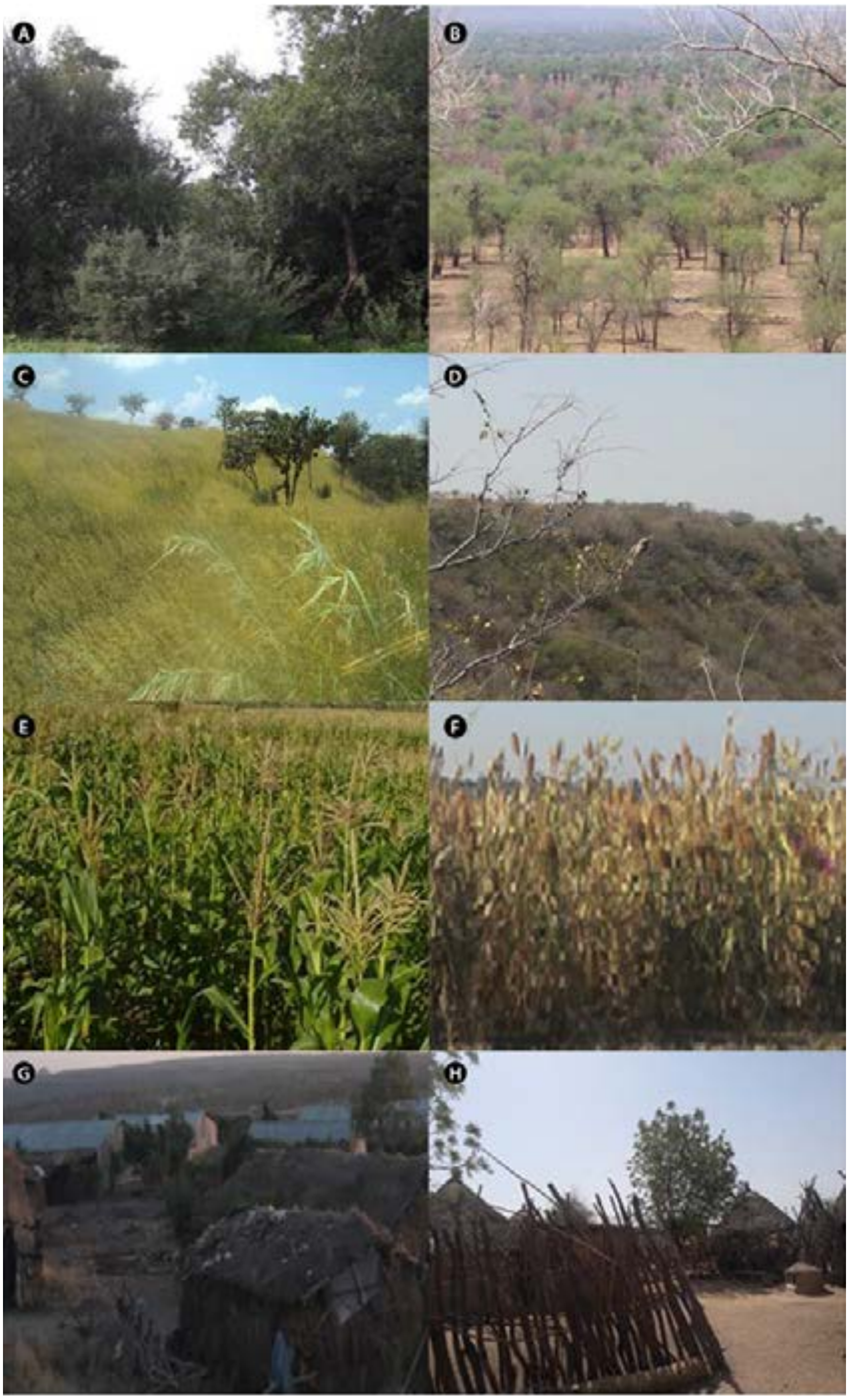

Image 1. Habitat types of Kafta-Sheraro National Park (KSNP), Ethiopia where rodent surveys were carried out; A & B - Natural forest | C - Grassland | D - Bushland | E - Farmland (Maize) | F - Farmland (Sorghum) | G - Human settlements (Adigoshu Military Camp) | H - Human settlements (Adebay Town). © Alembrhan Assefa.

species identification was further checked using cranio-dental morphology and morphometric measurements. Voucher specimens were compared with the specimens in the collection of the Zoological Natural History Museum of Addis Ababa University, Addis Ababa.

The collected data were analyzed using SPSS version 22 computer software programme. Two-way ANOVA was used to test the significant variation of rodent species trapped across different habitat types, seasons, sex, and age groups. Species richness and diversity were computed using Shannon-Weaver diversity index (Shannon & Weaver 1949). Shannon-Weaver diversity index was calculated using the formula H′= ∑ (Pi) ln (pi). Where, H′ - Shannon-Weaver diversity index, Pi - proportion of the total individuals belonging to i^{th} species in the sample, ln - the natural logarism and ∑ - sum of the calculations. Evenness (E) was calculated using the formula, E = H′/ H'_{max}. Where, H'_{max} = ln (S), S is the number of species and H′ is Shannon diversity index. We used PAST software (Hammer et al. 2001) to prepare the species accumulation curve (Mao Tau function) to assess representativeness of the sampling effort of rodents during the study.

RESULTS

Totally ten species of rodents were recorded in the study, of which seven species were trapped, and three species were directly sighted. The trapped species included *Mastomys natalensis* (Smith, 1834), *Stenocephalemys albipes* (Rüppell, 1842), *Rattus rattus* (Linnaeus, 1758), *Mastomys awashensis* (Lavrenchenko, Likhnova & Baskevich, 1998), *Acomys cahirinus* (É. Geoffrey, 1803), *Arvicanthis niloticus dembeensis* (Rüppell, 1842) and *Mastomys erythroleucus* (Temminck, 1853), while the sighted species *Lemniscomys striatus* (Linnaeus, 1758)*, Hystrix cristata* (Linnaeus, 1758), and *Xerus rutilus* (Cretzschmar, 1828). *Mastomys awashensis* and *S. alpibes* are among the endemic rodent species of the country. A total of 258 captures of 209 individual rodents were trapped in 2940 trap nights during both the wet and dry seasons of the study. Of these 209 were new captures and 49 were recaptured. The total number of captures varied among species. *Mastomys natalensis* was the most abundant species constituting 41.1% of the total number of captures, followed by *S. albipes* (26.3%) and *R. rattus* (18.2%), respectively and *M. erythroleucus* (1.4%) was the least abundant species (Table 1).

M. natalensis and *R. rattus* were recorded in all habitat types (Fig. 2), while *S. albipes* and *M. awashensis* were captured in four habitats and absent from grasslands, *A. cahirinus* and *A. n. dembeensis* were captured in three habitats and absent from natural forests and farmlands, and *M. erythroleucus* was captured only from natural forest and farmland habitats. In the natural forests, *S. albipes* was the most captured species followed by R. rattus, while in all the other habitat types *M. natalensis* dominated (Table 2). There was significant variation in total number of captures with respect to species (Two-Factor ANOVA: $F_{6,4}$ = 19.339, $p < 0.05$) but not among habitat types (Two-Factor ANOVA: $F_{4,24}$ = 1.507, NS).

The species richness, diversity, and evenness of rodents varied among habitat types (Table 3). The highest species richness was recorded from bushland and human settlement habitats (6 species each), while the least was in grassland (4 species). The highest Shannon-Weaver diversity index was observed in human settlement (H′ = 1.41), followed by bushland (H′ = 1.25) and the least was in grassland (H′ = 1.11) habitats. Grassland recorded the highest evenness (E = 0.800) and bushland had the lowest evenness (E = 0.695). The species accumulation curve for all habitat types (Fig. 3) has fully reach asymptote indicating that no more sampling effort is needed to capture all the expected rodent species of the park.

The number of captures and abundance of rodents during the wet and dry season was 128 (61.2%) and 81 (38.8%), respectively. During the wet season, *A. n. dembeensis* (75%), *S. albipes* (69.1%) and *M. natalensis* (58.1%) were highly recorded. *A. cahirinus* (83.3%) was recorded highly during the dry season while, *A. n. dembeensis* was the least recorded (25.0%). *M. erythroleucus* was only captured during the dry season (Table 4). The total number of captures of rodents did not vary significantly between seasons (Two-Factor ANOVA: $F_{4,15}$ = 0.732, NS).

The sex ratio is in favour of females (1:1.48) with 59.8% of the total captures being female specimens (Table 5). In the wet season, more females than males were captured, but in the dry season the captures were more or less equal for both the sexes. There was significant variation between male and female individuals of *M. natalensis* (Two-Factor ANOVA: $F_{1,4}$ = 4.745, $p < 0.05$), *A. cahirinus* (Two-Factor ANOVA: $F_{1,4}$ = 6.000, $p < 0.05$), and *A. n. dembeensis* (Two-Factor ANOVA: $F_{1,4}$ = 4.800, $p < 0.05$). Only *M. natalensis* (Two-Factor ANOVA: $F_{4,4}$ = 3.220, $p < 0.05$) and *S. albipes* (Two-Factor ANOVA: $F_{4,4}$ = 5.756, $p < 0.01$) have shown significant variation with respect to sexes in different habitats.

Adult rodents comprised the highest number of individuals (52.2%), followed by sub-adults (32.0%) and juveniles (15.8%) (Table 6). The number of individuals of all age groups was higher during the wet season than the dry season. Significant variation was observed among different age groups only in *M. natalensis* (Two-Factor ANOVA: $F_{2,4}$ = 5.756, $p < 0.01$), *S. albipes* (Two-Factor ANOVA: $F_{2,4}$ = 3.310, $p < 0.05$), and *A. cahirinus* (Two-Factor ANOVA: $F_{2,4}$ = 6.000, $p < 0.01$).

Table 1. Species composition, relative abundance (RA) and conservation status (CS) of rodents in Kafta-Sheraro National Park (KSNP), Ethiopia.

Family	Scientific name	Common name	Total	RA (%)	CS	Voucher no.
Muridae	*Mastomys natalensis* (Smith, 1834)	Natal Multimammate Mouse	86	41.1	LC	ZNHM.AAU.KSNP-R.07.2017
	Stenocephalemys albipes (Rüppell, 1842)	Ethiopian White-footed Mouse	55	26.3	LC	ZNHM.AAU.KSNP-R.04.2017
	Rattus rattus (Linnaeus, 1758)	Black Rat/Roof Rat	38	18.2	LC	ZNHM.AAU.KSNP-R.09.2017
	Mastomys awashensis (Lavrenchenko, Likhnova & Baskevich, 1998)	Awash Multimammate Mouse	17	8.1	VU	ZNHM.AAU.KSNP-R.02.2017
	Acomys cahirinus (É. Geoffrey, 1803)	Cairo Spiny Mouse	6	2.9	LC	ZNHM.AAU.KSNP-R.10.2017
	Arvicanthis niloticus dembeensis (Rüppell, 1842)	African Grass Rat	4	1.9	LC	ZNHM.AAU.KSNP-R.13.2017
	Mastomys erythroleucus (Temminck, 1853)	Guinea Multimammate Mouse	3	1.4	LC	ZNHM.AAU.KSNP-R.11.2017
	Lemniscomys striatus (Linnaeus, 1758)	Typical Striped Grass Mouse	#	#	LC	-
Hystricidae	*Hystrix cristata* (Linnaeus, 1758)	Crested Porcupine	#	#	LC	-
Sciuridae	*Xerus rutilus* (Cretzschmar, 1828)	Unstriped Ground Squirrel	#	#	LC	-
Total			209	100		

= sighted species, CS = IUCN status, LC = Least Concern, VU = Vulnerable, ZNHM.AAU = Zoological Natural History Museum of Addis Ababa University, KSNP-R = Kafta-Sheraro National Park Rodent voucher number, - = no voucher number.

Table 2. Number and abundance (%) of rodent species among habitat types of Kafta-Sheraro National Park (KSNP), Ethiopia.

Species	Habitat types				
	NF	BL	GL	FL	HS
M. natalensis	7 (14.28)	16 (39.02)	14 (58.33)	29 (41.42)	20 (41.66)
S. albipes	28 (57.14)	18 (43.90)	-	6 (8.57)	3 (6.25)
R. rattus	9 (18.36)	3 (7.31)	5 (20.83)	7 (10.00)	14 (29.16)
M. awashensis	3 (6.12)	2 (4.87)	-	4 (5.71)	8 (16.66)
A. cahirinus	-	1 (2.43)	3 (12.50)	-	2 (4.16)
A. n. dembeensis	-	1 (2.43)	2 (8.33)	-	1 (2.08)
M. erythroleucus	2 (4.08)	-	-	1 (34.28)	-
Total	49	41	24	47	48

NF = Natural forest, BL = Bushland, GL = Grassland, FL = Farmland, HS = Human settlement, – = no capture.

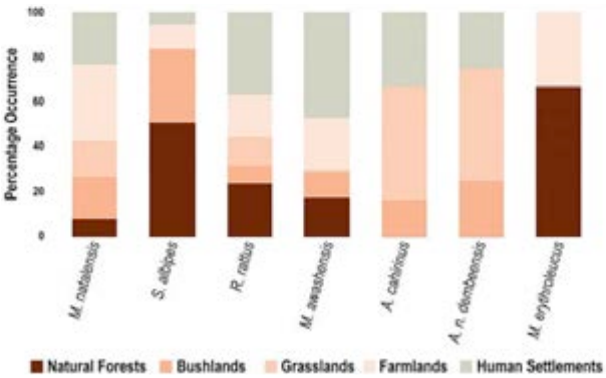

Figure 2. Percentage composition rodent species captured from five habitats in Kafta-Sheraro National Park (KSNP), Ethiopia.

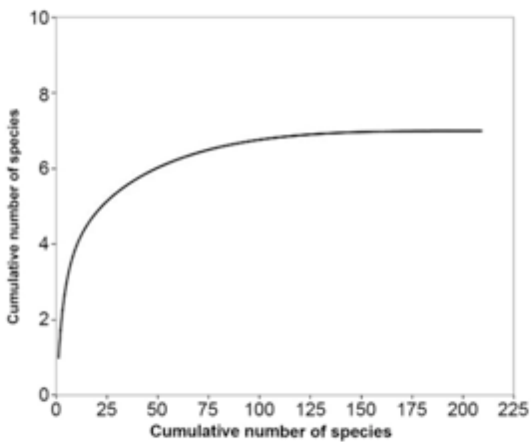

Figure 3. Species accumulation curve of rodent species in Kafta-Sheraro National Park (KSNP), Ethiopia.

Image 2. Rodents trapped during the present study at Kafta-Sheraro National Park (KSNP), Ethiopia; A - *Mastomys natalensis* | B - *Mastomys awashensis* | C - *Mastomys erythroleucus* | D - *Stenocephalemys albipes* | E - *Acomys cahirinus* | F - *Arvicanthis niloticus dembeensis* | G - *Rattus rattus.*

Table 3. Diversity indices of rodents among habitat types in Kafta-Sheraro National Park (KSNP), Ethiopia.

Habitat	No. of species	Total catch	H'	H_{Max}	E	D
NF	5	49	1.21	1.609	0.753	0.3861
BL	6	41	1.25	1.792	0.695	0.354
GL	4	24	1.11	1.386	0.800	0.4063
FL	5	47	1.14	1.609	0.705	0.4269
HS	6	48	1.41	1.792	0.787	0.2925

NF = Natural forest, BL = Bushland, GL = Grassland, FL = Farmland, HS = Human settlement, H' = Shannon-Weaver index, H_{Max} = natural logarithm of total number of species, E = Evenness, D = Dominance.

Table 4. Number and abundance (%) of rodents trapped during dry and wet seasons in Kafta-Sheraro National Park (KSNP), Ethiopia.

Species	Seasons		
	Wet	Dry	Total
M. natalensis	50 (58.1)	36 (41.9)	86
S. albipes	38 (69.1)	17 (30.9)	55
R. rattus	25 (65.8)	13 (34.2)	38
M. awashensis	11 (64.7)	6 (35.3)	17
A. cahirinus	1 (16.7)	5 (83.3)	6
A. n. dembeensis	3 (75.0)	1 (25.0)	4
M. erythroleucus	-	3 (100.0)	3
Total (%) No. of species	128 (61.2) 6	81 (38.8) 7	209 7

Table 5. Sex distribution of rodents between wet and dry seasons in Kafta-Sheraro National Park (KSNP).

Species	Wet season		Dry season	
	F	M	F	M
M. natalensis	33 (66.00)	17 (34.00)	21 (58.33)	15 (41.66)
S. albipes	27 (71.05)	11 (28.94)	9 (52.94)	8 (47.05)
R. rattus	16 (64.00)	9 (36.00)	7 (53.84)	6 (46.15)
M. awashensis	8 (72.72)	3 (27.27)	1 (16.66)	5 (83.33)
A. cahirinus	-	1 (100.00)	-	5 (100.00)
A. n. dembeensis	-	3 (100.00)	-	1 (100.00)
M. erythroleucus	-	-	3 (100.00)	-
Total	84 (65.62)	44 (34.37)	41 (50.61)	40 (49.38)

F = female, M = male.

Table 6. Age distribution of rodents captured between seasons in Kafta-Sheraro National Park (KSNP), Ethiopia (values in parenthesis are percentage of age class in particular season).

Species	Juvenile		Sub-adult		Adult	
	Wet	Dry	Wet	Dry	Wet	Dry
M. natalensis	10	5	18	9	22	22
S. albipes	7	1	15	5	16	11
R. rattus	5	1	9	5	11	7
M. awashensis	3	0	3	2	5	4
A. cahirinus	0	0	0	0	1	5
A. n. dembeensis	1	0	0	0	2	1
M. erythroleucus	0	0	0	1	0	2
Total	**26 (20.31)**	**7 (8.64)**	**45 (35.15)**	**22 (27.16)**	**57 (44.53)**	**52 (64.19)**

DISCUSSION

A total of 10 species of rodents were identified. Relatively similar representations of rodents were recorded previously in different protected areas of Ethiopia (Tilahun et al. 2012; Getachew & Afework 2015). High numbers of rodent species were reported from Alatish National Park, Chebera-Churchura National Park and Chilalo-Galama Mountain range (Tadesse & Afework 2008). Various levels of habitat productivity, habitat structure and complexity, risk of predation, food availability, human activities, and cattle grazing influence species richness. KSNP is highly disturbed by anthropogenic activities such as gold mining and forest destruction for agricultural expansion and charcoal production. Along with these biotic interventions livestock grazing is also rampant. These may be detrimental in rodent distribution within the park.

M. natalensis was the most abundant and widely distributed species in all habitat types studied, and was recorded in different habitat types including human settlements, and is considered as the most common pest species (Demeke et al. 2007; Tadesse & Afework 2008). Our observation on the abundance of this species agrees with earlier studies (Tilahun et al. 2012). However, higher abundance of *M. natalensis* has been reported in different areas (Manyingerew et al. 2006; Mohammed & Afework 2011; Mulungu et al. 2013). The high abundance of *M. natalensis* in different environments and habitats in its range could be due to its high reproductive potential, large litter size, ecological adaptability, and opportunistic food habit.

S. albipes was the second most abundant rodent species, is highly associated and abundant in natural forest habitats. Yalden & Largen (1992) reported *S. albipes* as one of the most abundant and common endemic rodent species of Ethiopia. Similar abundance was reported from other areas in Ethiopia (Mohammed & Afework 2011), however, low abundance of this species was also reported by others (Tadesse & Afework 2008; Tilahun et al. 2012). *Rattus rattus* was the third most abundant rodent species in the study area, and was mostly associated with human settlements, an observation that agrees with Moussa et al. (2015). This species was as least abundant Wonji sugarcane plantation and Chebera-Churchura National Park (Serkebirhan et al. 2011); however, Meheretu et al. (2014) reported this species to be abundant.

The abundance of *A. cahirinus* in this study was consistent with earlier reports (Tilahun et al. 2012; Getachew & Afework 2015). Unlike the present study, high abundance of *A.* n. *dembeensis* were reported in different parts of Ethiopia (Tilahun et al. 2012). *M. erythroleucus* is the most and important maize pest in eastern Africa (Odhiambo et al. 2005), and it was the least abundant species recorded in the study. Interestingly, many individuals of this species were trapped from natural forests. Similar findings were reported by Tadesse & Afework (2008). Afework & Leirs (1997) reported the highest abundance of this species in Central Ethiopia. Variations in the abundance of these species in different areas might be due to the variations in vegetation cover, food supply, and predators.

The highest species richness and diversity of rodents in bushland and human settlement habitat types contradicts with the findings of Demeke et al. (2007) and Moges & Dessalegn (2015), who reported that the bushland is structurally simple and comprises low biotic diversity. As compared to other habitat types of KSNP, bushland and human settlement habitats deliver relatively high shelter and food sources for rodents throughout the year.

The total number of captures and abundance of rodents was higher during the wet season than dry season, and agrees with those of Dawit & Afework (2008), (Serkebrerhan et al. 2011), and (Tilahun et al. 2012). Since the park is characterized by a uni-modal type of rainfall regime, high rainfall occurs during the wet season, as a result, there may be adequate shelter and food resources, which can contribute to high number of trapped individual rodents than the dry season. Several studies revealed that seasonal variation in weather conditions like rainfall affects the nutritional aspects, life strategies, and reproductive potential of rodents (Makundi et al. 2006; Tadesse & Afework 2008).

The sex ratio was found to be female biased, with more number of females captured than the males. Similar observations were reported by Tadesse & Afework (2008), however, in some areas male biased sex ratio was also reported (Manyingerew et al. 2006; Dawit & Afework 2008). This variation might be due to factors such as availability of food and microclimatic niches favouring females than males. Males being more abundant than the females could be due to their increased activity (Getachew & Afework 2015).

Out of the total trapped individuals, most captures were that of adults, and the least were that of juveniles. The probability of capturing more adults is may be due to their large home range, active movement, and fast capture ability. Adult animals have a higher social ranking, and cover wide home ranges, which causes higher capture rate than young individuals (Shanker 2001; Workneh et al. 2006). Higher numbers of individuals of all age groups were recorded during the wet seasons than dry seasons, and agree with findings of Makundi et al. (2006) and Getachew & Afework (2015). The seasonal variation among age groups might be due to the relationship between rainfall, seasonality in reproduction and seasonal based movement of rodents outside their home. During the present study, pregnant females of only four species were trapped. Higher pregnant females were recorded during the wet season than dry seasons, indicating that the more species reproduce more often in the wet season that may related with increased availability of food resources. Makundi et al. (2006) notified that seasonal variations in weather condition, mainly the rainfall, determine the nutritious features, which influences rodent reproduction.

During the present study, we have also observed that some rodent species including *H. cristata*, *A. n. dembeensis*, *S. albipes*, and *M. natalensis* are consumed as food locally by the indigenous Kunama ethnic group. Tadesse & Afework (2008) and Assogbadjo et al. (2005) also reported the economic importance of rodents as food source for Gumuz people, Ethiopia and Benin, respectively. This could be due to the high nutrient content in meat of rodents and hunting-based feeding habit of the people. The present study reveals that rodent diversity in KSNP is a reflection of the habitat quality and their composition and abundance in different habitat types and seasons varied. Long-term monitoring and detailed studies on ecological aspects of the rodents is suggested for future to provide more scientific information and insights on the rodent diversity in one of the least-explored and eco-sensitive protected areas of Ethiopia.

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Colour aberration in Indian mammals: a review from 1886 to 2017

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Abstract: The phenomena of colour aberration (albinism, leucism, piebaldism, melanism, hypomelanism, and blue-eyed colour morph) is reported in various mammalian species throughout the world including India. A total of 239 such instances in Indian mammals was tabulated in this study along with maps showing locations of the records. The records from 1886 to 2017 (till July) were gathered from published scientific literature, magazines, and images uploaded on various websites. The records were reviewed along with their order-wise and family-wise representation and were analyzed. Appropriate identification of colour aberration was attempted on the basis of any presented evidence. Altogether, 56 (out of 421) mammalian species belonging to eight orders and 19 families were reported to exhibit various types of colour aberrations, amounting to 13.3% of the total mammalian species found in India. Of these, albinos constituted 21.8%, leucistic 14.2%, piebald 5.4%, melanistic 25.5%, hypomelanistic 18.4%, and blue-eyed white morph 1.3%; the remaining 13.4% was undetermined. The study highlights 1) the absence of records of colour aberrations in the largest mammal family Vespertilionidae, which contrasts with studies elsewhere, 2) the persistent occurrence of albinos in Spotted Deer and Blackbucks in Gujarat, 3) the high number of melanistic leopards in India over the years and recent instances of melanistic Asian Golden Cats in Sikkim, 4) regular records of hypomelanism in Gaurs of the southern Western Ghats except in the last few years. Overall, a need for further studies in colour aberration in mammals is urged.

Keywords: Albinism, blue-eyed colour morph, chromatic disorders, hypomelanism, leucism, mammals, melanism, piebaldism.

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INTRODUCTION

The characteristic skin in mammals is clothed with fur or hair and its concealment may be effected by the colour and pattern of the coat. The colouration in animals is a function of selective pressures that can be divided into three categories: concealment, communication, and regulation of physiologic processes (Caro 2005). Generally, the coat colour change depends on the surrounding seasonal climate conditions and also the geographic regions where they are found (Menon 2003). Besides this, the age, sex, health, and nutrition play important roles in the looks of an animal. Mammals also show individual coat or pelage differences even within the same race and this is particularly so in the case of genetic mutations such as albinism, melanism (Menon 2003), and other types of colour aberrations such as leucism, piebaldism, hypomelanism, and blue-eyed white morph.

The colour aberrations are variously termed as colour variation (Hofreiter & Schöneberg 2010), anomalous colouration (Abreu et al. 2013), atypical colouration (Zalapa et al. 2016), and chromatic disorder (Lucati & Lopez-Baucells 2016). The phenomenon of colour aberration is not uncommon in vertebrate groups including birds and mammals. The most common pigment in both birds and mammals is melanin (Fox & Vevers 1960) and the pigmentation process in mammal hair is identical to that in bird feathers (Lubnow 1963; van Grouw 2013). There are two forms of melanin: eumelanin and phaeomelanin (Lubnow 1963). Depending upon the concentration and distribution within skin and fur, eumelanin is responsible for black, grey, and/or dark brown colours whereas phaeomelanin is responsible for warm, reddish-brown to pale buff colours. Both melanins together can give a wide range of greyish-brown colours (Lubnow 1963; van Grouw 2013). The development of melanin is the result of a biochemical process called melanin synthesis in melanin-producing cells (melanocytes); the amino acid tyrosine and enzyme tyrosinase are necessary to start this synthesis. Further, every disturbance or the heritable cause, i.e., genetic mutation, at every stage of melanin synthesis affects the concentration and distribution of melanin resulting in an aberrant colour (van Grouw 2013).

The colour aberrations in mammals were described using various terms such as albinism (pure/complete), partial albinism, melanism, and erythrism. There is no consensus on standard terminology to describe the aberrations accurately. Recently, van Grouw (2006, 2013) and Mahabal et al. (2016) produced an excellent identification key to name the colour aberrations in birds. Although identifying colour mutations in the field can be extremely difficult, this key makes it possible to name many mutations correctly. The mammals await such imminently usable identification key.

Abreu et al. (2013) and Lucati & Lopez-Baucells (2016) attempted to classify the aberrations for their study of bats. We mostly continued the use of terminology based on these literature. The terms used in this study are summarised in Table 1 and further details are provided below.

Albinism is a hypo-pigmentary disorder with a total lack of both melanins in hairs, eyes, and skin due to the heritable absence of functional tyrosinase enzyme in pigment cells affecting all skin and hairs, resulting in a total white plumage/fur with red eyes. Albinism is controlled via inheritance by an autosomal recessive gene in all animal species (Hale et al. 2005; van Grouw 2006, 2013).

Leucism is a total lack of pigmentation in the whole body due to an inherited defect in the pigment transfer process effecting white or whitish hair, pale skin, but normal coloured eyes (van Grouw 2006; Abreu et al. 2013; Lucati & Lopez-Baucells 2016).

Piebaldism is a type of hypopigmentation in which the absence of pigment is localized and is due to an absence of melanocytes in the affected skin and hair follicles as a result of genetic mutation. This is similar to leucism but differs in that the melanocyte development is only locally disrupted. Piebald animals have a variable distribution of white spots on the body but have normal coloured eyes (Lucati & Lopez-Baucells 2016). Although not used widely, it seems to be the least confusing term to denote those cases where the colour aberration affects only part of the body.

Hypomelanism is another type of hypo-pigmentation wherein an inherited colour aberration results in a fawn, cream, grey, grey-brown, ashy, whitish-yellowish, light golden-brown, or orange to light red individual with insufficiently pigmented skin. This is mainly due to mutations affecting melanin biosynthesis resulting in pigment reduction in one or both of the two melanin forms leading to various colour morphs (van Grouw 2006, 2013; Lucati & Lopez-Baucells 2016; Mahabal et al. 2016).

Melanism is the opposite condition of albinism wherein there is an excessive synthesis of melanin pigment in the skin resulting in a melanistic (black to dark reddish-brown morph) animal (van Grouw 2006, 2013; Lucati & Lopez-Baucells 2016; Mahabal et al. 2016).

Blue-eyed white morph: Blue-eyed white morph in some instances of tigers and leopards is a morph with dominant genes seen effecting a light ivory-coloured to white or creamy white fur with typical black-brown stripes, pink nose and pads, and pale blue eyes (Pant & Dhariyal 1979). In tigers, this mutation primarily affects the red/yellow pheomelanin pathway (Xu et al. 2013).

A number of instances of colour aberrations occurred and were recorded in various vertebrate species throughout the world including India. In this context, instances of colour aberrations were reviewed in herpetofauna (Mahabal & Thakur 2014) and birds (Mahabal et al. 2016) in India from 1886 to 2013 and 2015, respectively. Indian mammals needed detailed attention in this regard. In other parts of the world, some researchers tackled this topic sporadically in various species (Macnaghten 1918; Allen 1939; Setzer 1950; Pirlot 1958; Jones 1973; McBride 1977; Howell 1980; Smith 1982; Morris & Tutt 1996; Uieda 2000; Hsu 2003; Acevedo & Aguayo 2008; McCardle 2012; Abreu et al. 2013).

The current communication intended to review the instances of all types of colour aberrations recorded in Indian mammals since 1886, including the 54 records (marked * in Table 2) assessed by Singh (2014). The study by Singh (2014) made a scientometric analysis of the availability and dissemination of information on 'true albino' and 'white' mammals accessed for the period 1886–2014 in Indian sources usually consulted by wildlife and natural history workers. Our focus of study, however, was a comprehensive compilation of all types of colour aberrations recorded in various mammalian species, its order-wise and family-wise representation, and its analysis. The geographic distribution pattern of these aberrations was also provided.

METHODS

In this study, the scattered records on colour aberrations (albinism, leucism, piebaldism, melanism, and others) in Indian mammals were gathered from published scientific literature available in print as well as in digital databases such as JStor, EBSCOHost, and open access journals. We also searched for photographic records available in various print resources such as newspapers and magazines and in electronic media including platforms and websites (such as India Nature Watch, Flickr, and Facebook). The reviewed records range from 1886 to 2017 (till July) including some historic records dating back to the years 1561, 1608, and 1820.

For tabular presentation of the data on records of instances of colour aberrations of the species, we followed taxonomic sequence and scientific and common names as per Pradhan & Talmale (2012); we also provided the type and description of aberration as per the original author, our interpretation of the aberration, locality with geographic coordinates (if available), date, sex, remarks (if any), and the source of information. In some instances, we noticed possible misidentification of the type of colour aberration and tried to deduce the more appropriate type based on any evidence present in the text or any accompanying images. Wherever the evidence was insufficient to accurately determine the aberration, for example, missing details of the colour of eyes which is essential to separate albinism from

Table 1. Terminology used to describe colour aberrations adopted from van Grouw (2006, 2013), Abreu et al. (2013), Lucati & Lopez-Baucells (2016), and Mahabal et al. (2016) except for the blue-eyed white morph.

Aberration	Effect on melanin	Resulting phenotype	Other names
Albinism	Total lack of both melanins in skin, hair follicles, and eyes due to the heritable absence of the enzyme tyrosinase in pigment cells.	All-white hair, pale skin, and red eyes.	Total/pure/complete/perfect albinism; total amelanism
Leucism	Total lack of both melanins in all of the hair follicles and skin due to the heritable absence of pigment cells caused by the failure of melanocytes to migrate to the skin and hair follicles.	All-white or whitish hair, pale skin; eyes and/or body extremities normally coloured.	
Piebaldism	Total lack of melanin in part of the skin and/or hair follicles due to the heritable absence of melanocytes in the affected part.	All-white fur/skin patches; eyes always normally coloured.	Part albino
Melanism	Abnormal deposition of melanin (not necessarily an increase of pigment) in the skin and/or hair follicles.	Increase of black and/or reddish-brown or altered pattern.	Nigrism
Hypomelanism	Mutations affecting melanin biosynthesis, pigment granule trafficking, or membrane sorting.	Beige, brown, golden, yellowish or reddish fur; skin and eyes always normally coloured.	Erythrism; flavism; rufism; silvering; tawny; dilution
Blue-eyed white morph	Pheomelanin is largely absent, eumelanin is present in the eyes and in the hairs of stripes. Mostly seen in tigers and leopards.	Blue eyes, pale/white fur, stripes/spots brown/sepia/dull orange.	

leucism, we marked them as undetermined.

Geographic information and mapping

For each occurrence, we tried to ascertain the precise geographic location based on the information provided. Some of the records, especially the recent ones, give the exact geographic coordinates. In many records, however, the coordinates associated with the locality have the limitation of not being the exact location of the observation due to lack of precise information. In such cases, a central point within the locality/area was taken. The data was plotted and georeferenced onto the map of India using QGIS v. 2.12.2 (Open Source Geospatial Foundation, Lyon).

RESULTS AND DISCUSSION

Altogether, 239 instances of various colour aberrations recorded in Indian mammals over a period of 130 years were compiled in Table 2. The Indian mammalian fauna is represented by 420 species belonging to 48 families and 14 orders (Pradhan & Talmale 2012). This communication has one additional species (Indian Cheetah *Acinonyx jubatus*), which has since become extinct and hence is excluded from Pradhan & Talmale (2012). The family-wise distribution of the known species, number of aberrant colour species, and occurrence of the number of instances in various types of colour aberrations were summarized in Table 3.

The analysis of Tables 2 and 3 reveals that only 56 species (out of 421 known mammalian species, including 420 extant and one extinct species from the region) belonging to eight orders and 19 families were reported to exhibit various types of colour aberrations amounting to 13.3%. Of these, albinos constituted 21.8%, leucistic 14.2%, piebald 5.4%, melanistic 25.5%, hypomelanistic 18.45%, and blue-eyed white morph 1.3%; the remaining 13.4% was undetermined. Most of the records under 'undetermined' were either albinos or leucistic animals; however, the eye colour, which is red/pink in albinos and normal in leucistic animals, was not noted by the original authors.

Figures 1 and 2 illustrate the spread of the occurrences of colour aberrations on the map of India. The reports of colour aberrations were recorded from various regions of India with a noticeable gap in the Deccan plateau region of Maharashtra, Telangana, Andhra Pradesh, and Karnataka states, possibly due to lack of published records. Very few instances of colour aberrations in mammals were reported from this region. Records of albinism and leucism are widespread across the country. Blue-eyed white morph, however, seems to be mostly from the eastern and central parts. Records of melanistic animals were mostly from the forested areas of the Western Ghats, the foothills of the Himalaya, and central India. The instances of hypomelanism are peculiarly concentrated in the southern Western Ghats straddling the states of Kerala and Tamil Nadu. The bulk of these records is those of the Gaur. Both melanistic and hypomelanistic instances were almost negligible in the northwestern states of Punjab, Haryana, Rajasthan, and Gujarat. In fact, there is no record of any colour aberration in mammals from the states of Haryana, Arunachal Pradesh, Tripura, and Mizoram (Table 4). While states like Maharashtra, Madhya Pradesh, and Tamil Nadu have many records of colour aberration compared to other states, states like Chhatisgarh, Jammu & Kashmir, Jharkhand, Meghalaya, Nagaland, and Telagana have only one record each of any colour aberration. The gaps mentioned above indicate a need for more observations.

The instances of colour aberrations were more pronounced in the families Felidae (76), followed by Bovidae (42) and Cervidae (36). Felidae also exhibited the maximum number of instances of melanistic animals (46), particularly in leopards (32), tigers (8), and jungle cats (3). The highest number of instances of hypomelanism (11) was noticed in Gaur (Bovidae), followed by Sloth Bear (8; Ursidae) and macaques (7; Cercopithecidae). Cervids showed the highest number of albinistic animals (16), followed by squirrels (10; Sciuridae). Blackbucks (Bovidae) showed the highest number of instances of leucism (6). Piebaldism was quite uncommon with most instances in Muridae (5). Similarly uncommon, almost all instances of blue-eyed white morph animals were recorded in leopards and tigers (Tables 2 & 3).

The earliest record of colour aberration in India is of a tigress with her cubs in 1561 in the Mughal period from Gwalior-Malwa area of central India (Divyabhanusinh 1987a; Xu et al. 2013). Thereafter, from 1820 to 1978, a number of wild 'white' tigers were reported from the central and eastern states of India. It is unclear whether these were albinos, leucistic, or blue-eyed white morphs as the colour of eyes of the species were not recorded.

In May 1951, a wild 'white' tiger was caught and reared in the Maharaja's palace of Govindgarh in Rewa State (Madhya Pradesh), which was later named 'Mohan' (Oswald 1960; Divyabhanusinh 1987a). Singh (1999) described the 12 known types of body colours in

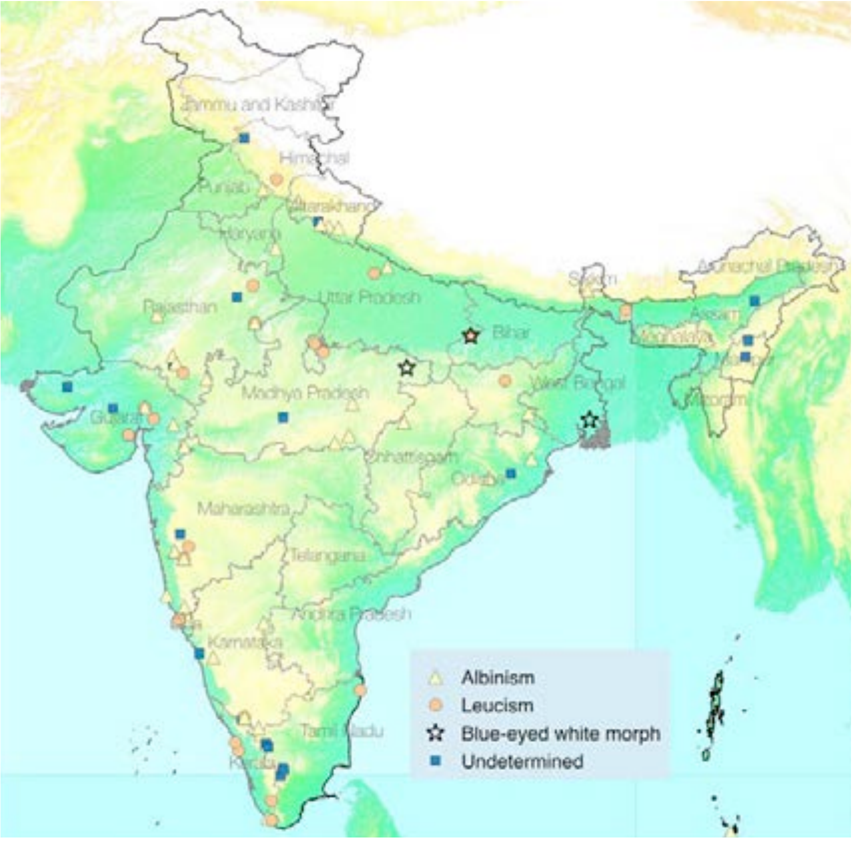

Figure 1. Occurrence of mammals with colour aberrations such as albinism, leucism, blue-eyed morph, and those that are undetermined in India.

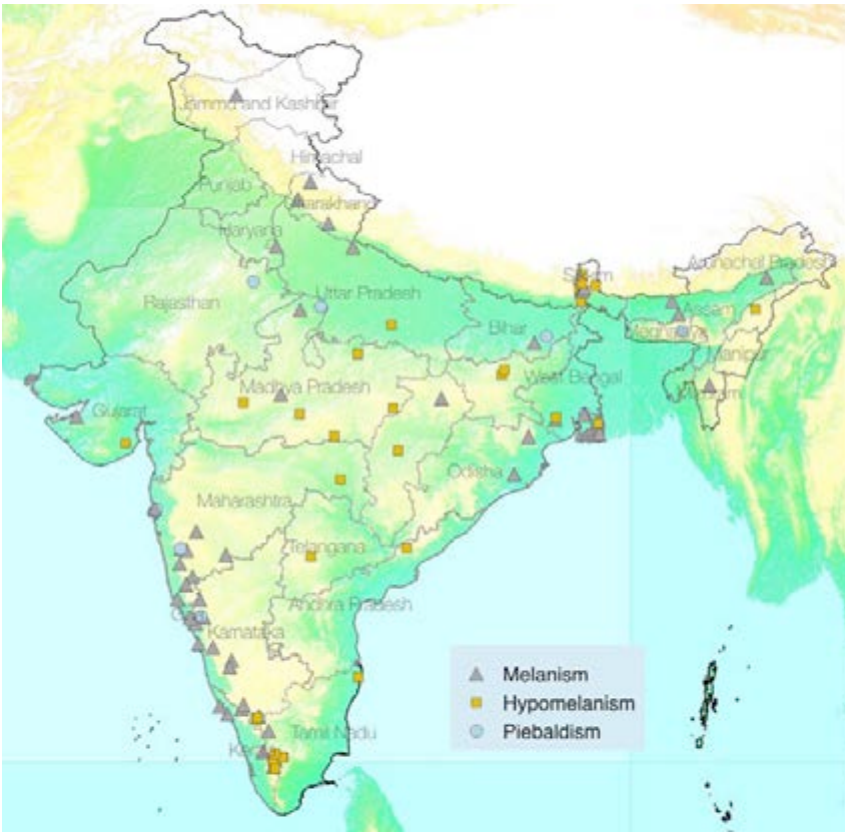

Figure 2. Occurrence of mammals with colour aberrations such as melanism, hypomelanism, and piebaldism in India.

tigers over a normal distribution curve and mentioned that there was an inclination to stretch the ancestry of most captive white tigers to Mohan of Rewa. Mohan was a blue-eyed white morph. A programme of captive breeding of this tiger was undertaken and its descendant stock is now in various zoos all over the world including India. Its genealogy was described by various authors (namely, Oswald 1960; Gee 1964; Sankhala 1969; Pant & Dahariyal 1979; Mishra et al. 1982; Singh 1996).

These captive instances of blue-eyed white morph tigers were not considered in this communication. Further, it is remarkable to note that after 1958 till date there are no published records of the occurrence of wild white tigers from any forested tracts of India. Singh (2010), during his stay from 2009 to 2010 in the white tiger country of Rewa forest in Madhya Pradesh, did not see any wild white tigers (Table 2). Therefore, it can be safely said that the wild strain of blue-eyed white morph tiger has diminished from India; however, it needs a scrupulous search from time to time.

The order Chiroptera with 117 species stands rich among the class Mammalia; however, looking at the instances of colour aberration occurrences, it is negligible (Table 3). Only one type, i.e., albinism, was reported in seven species of bats belonging to four different families covering nine instances. This shows that albinism is rare in bats as also opined by Khajuria (1973) and Hsu (2003). Hsu (2003), however, stated that the highest number of known albino cases was recorded in evening bats of the family Vespertilionidae at the global level (42.2%), as reviewed by Uieda (2000). In India, this family contains 58 known species of evening bats; however, it is intriguing to note that there is not a single instance of any type of colour aberration recorded from this largest family of Indian mammals. One of the reasons for this could be that "bats have not received adequate attention in biodiversity research in India" (Debata & Palita 2018) and the other could be that the occurrence of albinism is indeed rare in the group. Calderon-Alvarez & Marin-Vasquez (2018) studied colour aberration in the Short-tailed Fruit Bat *Carollia perspicillata* and support the view that the cause of variation in instances of albinism in families is unknown, but it appears to occur in species that are both social in their breeding habits and also fairly sedentary.

Albino individuals are more conspicuous as compared to normal individuals. In prey species, they are at a definite disadvantage in the struggle for existence and very few albinos manage to escape their natural enemies and survive to attain sexual maturity. For this reason, albino individuals are only sporadically reported. Albinism, however, is regularly reported in Spotted Deers across various regions of the country. Also, we see persistent records of albino Blackbucks in the region around Ahmedabad in Gujarat, including the Velavadar Blackbuck National Park (Table 2). The albinos in these populations, therefore, can make good candidates for studies about the effect of albinism on prey-predator relationship as well as on social behaviour within the herd. Additionally, the phenomenon of persisting albinism in Blackbucks of Velavadar Blackbuck NP is worth investigating.

Instances of black or melanistic leopards were recorded in various states from 1889 onwards almost regularly, indicating that the population of melanistic morph is well established in the country (Table 2). This was substantiated by the camera trapping studies since 2008 by Karanth (2014) in several wildlife sanctuaries, namely, Anshi, Dandeli, Bhadra, and Bandipur in Karnataka and Waynad in Kerala. About 10% of captured images of leopards belong to black leopards, appearing less rare than originally thought. Bashir et al. (2011) hypothesized that a number of melanistic forms of Asiatic Golden Cat captured in camera traps in different parts of Prek Chu catchment area of Khongchendzohga Biosphere Reserve, Sikkim, were either all melanistic or of a different subspecies. It is apparent from the above information that molecular study needs to be undertaken on priority to establish the genetic identity in different populations of melanistic leopards spread over the country and the Asiatic Golden Cats from Sikkim.

Singh (1999) is of the opinion that except for black panthers (leopard), all other leopards and tigers with colour aberration were discarded by natural processes; in the case of leopards, the black forms, although regularly seen, have not succeeded yet in replacing the normally spotted forms as the former are comparatively less fecund and viable.

Many hypomelanistic Gaurs *Bos gaurus* were regularly recorded by observers (Morris 1933, 1934, 1935, 1936b; Williams 1936, 1969; Davidar 1970; Gouldbury 1971; Ajith et al. 1998) between 1932 and 2000 in the mountains of Tamil Nadu and Kerala (Table 2). Since then, however, there are no published records of abnormal colouration in this species from that region. Naturalists visiting these mountains should carefully make notes of any colour aberrations in Gaur.

Table 2. Records of colour aberration in Indian mammals between 1886 and 2016 (taxonomy and sequence follow Pradhan & Talmale 2012).

	Taxa and common name	Description of aberration as given by the original author (with remarks, if any)	Most likely aberration (sex, if any)	Aberration as named by the original author	Locality (with decimal coordinates) and date (if any)	Source
	Order: Proboscidea **Family: Elephantidae**					
1*	*Elephas maximus* Linnaeus, 1758 Asian or Indian Elephant	Light pink skin with white hairs prominent on head, except at tip of tail giving pinkish-grey colour. Pearl eyes; mouth and palate light pink, toe and nails white. Usual black colour not visible. No change in colour even after a year.	Leucism (one female)	Albino either partial or complete	Karippanthode, 13 miles from Koni Central Forest Division, Travancore (9.096°N & 77.085°E) April 1945	Simon (1946)
	Order: Primates **Family: Cercopithecidae**					
2	*Macaca assamensis* (McClelland, 1840) Assamese Macaque	Dorsal fur colouration exceptionally bright burnt orange (as per author, no albino cases reported in this species).	Hypomelanism (one female)	Erythrism	Rongli (27.175°N & 88.747°E), Sikkim (in collection of BNHS, Mumbai, Specimen No. 5119) Between 1916 and 1938	Fooden (1982)
3	*Macaca assamensis*	Dorsal fur colouration exceptionally bright burnt orange.	Hypomelanism (one male)	Erythrism	Manshitang (27.596°N & 88.240°E), Sikkim (in collection of Z.M.B. Berlin, Specimen No. 91098) Between 1916 and 1938	Fooden (1982)
4	*Macaca assamensis*	Dorsal fur colouration exceptionally bright burnt orange.	Hypomelanism (one male)	Erythrism	Mokokchung (26.319°N & 94.512°E), Nagaland (in collection of BNHS, Mumbai, Specimen No. 5115) Between 1916 and 1938	Fooden (1982)
5	*Macaca assamensis*	Dorsal fur colouration exceptionally bright burnt orange.	Hypomelanism (one male)	Erythrism	Sookia Pokhari (26.998°N & 88.167°E), W.B. (in collection of BNHS, Mumbai, Specimen No. 5121) Between 1916 and 1938	Fooden (1982)
6	*Macaca assamensis*	Dorsal fur colouration tends to bright burnt orange; bright patch of deep chestnut on ventral surface of tail.	Hypomelanism (one adult female)	Erythrism	Gopaldharan (26.607°N & 88.220°E), W.B. (in British Museum, London. Specimen No. 25.1.11) Between 1923 and 1932	Hill (1974) as cited by Fooden (1982)
7	*Macaca mulatta* (Zimmermann, 1780) Rhesus Macaque	Completely white-bodied pair having red face, pink eyes and nails.	Albinism (one male and one female)	Albino	Zoo of H.H. Maharawat of Pratapgarh (24.033°N & 74.781°E), Rajasthan In 1942	Bahadur (1942b)
8*	*Macaca mulatta*	An individual with very pale, golden fur with normal coloured eyes. Image by Kedar Tambe.	Hypomelanism (young)	Albino	Pench N.P. (21.762°N & 79.338°E), M.P. May 2014	Anonymous (2014)
9*	*Macaca mulatta*	-	Albinism	Albino	Desert town of Bikaner, Rajasthan	Singh & Mohnot (2009)
10	*Macaca radiata* (E. Geoffroy, 1812) Bonnet Macaque or Monkey	A captive male with white fur and skin but brown irises	Leucism (one male)	White/ pigment absence	India, but exact locality not given (kept in London Zoo) In 1836	Ogilby (1838) as cited by Fooden (1981)
11	*Macaca radiata*	Pale golden brown in colour with abnormally reduced pigmentation.	Hypomelanism (one female sub-adult)	Pigment reduction	India, but exact locality not given (kept in US National Museum of Natural History (Species No. 1221717), Washington, D.C., U.S.A.	Fooden (1981)
12	*Macaca radiata*	A captive albino male with pink irises.	Albinism (one male)	Albino	Trivandrum Zoo (8.510°N & 76.955°E), southern India In 1936	Hill (1937) as cited by Fooden (1981)
13*	*Macaca radiata*	A medium-sized macaque with absolute white fur all over body including crown. Limbs and snout pinkish. Eyes reddish (image).	Albinism (one female)	Total albino	Valpoi Village (15.527°N & 74.136°E), Sattari, North Goa District, Goa November 2002	Mahabal et al. (2012)

	Taxa and common name	Description of aberration as given by the original author (with remarks, if any)	Most likely aberration (sex, if any)	Aberration as named by the original author	Locality (with decimal coordinates) and date (if any)	Source
	Order: Rodentia **Family: Sciuridae**					
14	*Ratufa indica* (Erxleben, 1777) Indian Giant Squirrel or Malabar Squirrel	A more reddish-brown body with varying shades of colour on face, between the ears and both the feet. Tail not completely black but dark reddish-brown patchily distributed between base and the tip, forehead and ear-tips darker.	Hypomelanism (one male)	Colour variation	Five miles north of Gungavadori Evergreen Forest (3,000ft; 10.200^{0}N & 77.499^{0}E) in Palani Hills, T.N. (in collection of BNHS, Mumbai) Before 1952	Abdulali & Daniel (1953)
15*	*Ratufa indica*	A pure white albino squirrel with pink eyes in the company of other normal-coloured squirrels.	Albinism (one adult)	Albino	Mahabaleshwar (4,000ft; 17.922^{0}N & 73.656^{0}E), Western Ghats, Satara District, Maharashtra (in collection of BNHS, Mumbai) 29 December 1952	Abdulali & Daniel (1953)
16	*Ratufa indica*	Totally white squirrel including tail, pink mouth and ears, pinkish limbs and blood red eyes. Moving in company of normal squirrels (image).	Albinism	Albino	Evergreen forest, Mahabaleshwar (4,000ft; 17.922^{0}N & 73.656^{0}E), Western Ghats, Satara District, Maharashtra 22 February and 23 April 2013	Sayyed et al. (2014)
17	*Ratufa indica*	Total white body with pinkish snout and reddish eyes visible in image (image by Vishwatej Pawar).	Albinism	Leucism	Satara (17.666^{0}N & 73.983^{0}E), Maharashtra, 01 April 2015	Anonymous (2016a)
18	*Eupetaurus cinereus* Thomas, 1888 Woolly Flying Squirrel	A jet black above and brownish-grey on forelimbs and membrane. Cheeks, chin, throat, chest, belly brownish with grey line along the middle of belly.	Melanism (one adult)	Melanism partial	Kashmir (34.0740^{0}N & 75.810^{0}E) (kept in Leyden Museum as reported by J. Anderson) Before 1879	Chakraborty & Agrawal (1977)
19*	*Callosciurus pygerythrus* (I. Jeoffroy Saint Hilaire, 1833) Hoary-bellied or Irrawaddy Squirrel	Complete white, tail faded white, eyes red and ear untufted (image).	Albinism (12 individuals with a baby)	Albino	From five different villages in Sibsagar District, Assam Between 1992 and 2005	Kalita (2009)
20*	*Callosciurus pygerythrus lokroides* (Hodgson, 1836) Hoary-bellied Himalayan Squirrel	In a pair male normal-coloured, female total white with no line of demarcation between dorsal and ventral. Eyes red (image).	Albinism (female)	Albino	Samsing (27.164^{0}N & 88.291^{0}E), Darjeeling District, W.B.	Bhattacharyya & Murmu (2004)
21	*Funambulus palmarum* (Linnaeus, 1766) Three-striped Palm Squirrel	Totally white with pinkish snout, ears and limbs, but normal-coloured eyes.	Leucism (one adult)	Leucism	Fragmented forested habitat of Gudalur Forest Division, Tamil Nadu (11.493^{0}N & 76.336^{0}E) 22 September 2016	Samson et al. (2017)
22	*Funambulus tristriatus* (Waterhouse, 1837) Jungle Palm Squirrel	Total white, bushy-tailed with snout, ears, and forelimbs pinkish. Eyes blood red. This individual was mingling with four normal-coloured squirrels (image).	Albinism (two adults)	Albino	Miramar Residency (15.496^{0}N & 73.808^{0}E), Panjim, Goa 24 April, 06 & 07 July 2015	Sayyed et al. (2015a)
23	*Funambulus tristriatus*	Squirrel with white patches on hindlimb on lateral side. Identical on other side. White hairs mixed with normal-coloured hair in tail region. Eyes, ears, snout, and limbs normal (image).	Leucism (one adult)	Leucistic-partial with bilateral symmetry	Miramar Residency (15.496^{0}N & 73.808^{0}E), Panjim, Goa 24 April, 6 & 7 July 2015	Sayyed et al. (2015a)
24	*Funambulus pennantii* Wroughton, 1905 Five-striped or Northern Palm Squirrel	Entire dorsum cream-buff without any visible stripe. Dorsum and ventrum do not show any difference. Naked skin area, anal opening with pinkish tinge, nails pale.	Leucism (one adult male)	Albinistic partially	Oudh (27.757^{0}N & 80.729^{0}E), U.P. (in collection of Z.S.I. Kolkata, Regd. No. 3798)	Agrawal & Chakraborty (1979)
25	*Funambulus pennantii*	The whole body covered with spotless white fur, dorsum does not show any sign of striped pattern. Eyes pink.	Albinism (one female)	Albinism	Chandigarh (30.732^{0}N & 76.779^{0}E) April 1981	Chaturvedi & Ghose (1984)

	Taxa and common name	Description of aberration as given by the original author (with remarks, if any)	Most likely aberration (sex, if any)	Aberration as named by the original author	Locality (with decimal coordinates) and date (if any)	Source
26*	*Funambulus pennantii*	A milky white albino sub-adult without dark-coloured stripes on back. Eyes bright red, ear pinnae also reddish.	Albinism (one sub-adult)	Albino	Udaipur City (24.603^{0}N & 73.701^{0}E), southern Rajasthan 06 September 2001	Sharma (2004)
27*	*Funambulus pennantii*	Total white adult with faint red spots and narrow stripes on the flanks. Forehead yellowish. Eyes pink. A young one total white with pink eyes near nesting site (image with editors).	Albinism (one adult and one young)	Total albinism	Deogad Fort (16.374^{0}N & 73.378^{0}E), Sindhudurg District, Maharashtra 22 November 2001, November 2002, and December 2008 at the same place by first author	Mahabal et al. (2005)
28	*Funambulus pennantii*	A white squirrel with a small brownish patch in the middle of dorsal side of the body. Eyes red (image with editors). Its father too was albino.	Albinism (two adults)	Albino	In residential area, northern Udaipur (24.619^{0}N & 73.686^{0}E), Rajasthan Mid-July 2005	Mehra et al. (2007, 2010)
29	*Funambulus pennantii*	Total white with pinkish snout, ears, and limbs. Two white median dorsal with whitish supplementary stripes. Eyes normal-coloured (image).	Leucism	Leucism	Andori (18.086^{0}N & 74.150^{0}E), near Lonand, Khandala Taluk, Satara District, Maharashtra 04 September 2015	Sayyed & Mahabal (2016)
30	*Funambulus* sp. Striped Palm Squirrel	Total white squirrel. No other details provided.	Undetermined (one adult)	Albinism	Near bungalow in Cutch (23.739^{0}N & 69.853^{0}E), Gujarat In 1886	Newnham (1886)
	Family: Muridae					
31	*Tatera indica* (*indica*) (Hardwicke, 1807) Indian Gerbil or Antelope	Pure white hairs all over the body including tail and eyelashes but iris black (unlike in albinos). Exposed skin devoid of pigmentation and translucent white, other three young ones normal-coloured.	Leucism (one young female)	White	Jodhpur (26.239^{0}N & 73.025^{0}E), Rajasthan In 1972	Prakash et al. (1973)
32	*Bandicota bengalensis* (Gray, 1835) Lesser Bandicoot Rat	A totally white with pinkish tinge, pink mouth and ears, red eyes (image).	Leucism (roadkill of adult)	Total albinism	Ajinkyadurg (17.666^{0}N & 73.983^{0}E), Satara, Maharashtra 17 January 2013	Sayyed et al. (2014)
33	*Bandicota bengalensis*	A totally white with pinkish tinge, pink mouth and ears, red eyes (adult captured live, photographed, and released).	Albinism	Total albinism	Ajinkyadurg (17.666^{0}N & 73.983^{0}E), Satara, Maharashtra 22 August 2013	Sayyed et al. (2014)
34	*Madromy blanfordi* (Thomas, 1881) Blanford's Rat	Out of 1213 rats trapped, one albino female captured, fur uniformly dull white along with tail, pink eyes. Mating experiment with normal male resulted all young ones normal-coloured in two litters.	Albinism (one female)	Albinism	Four miles from Sagar in forested area (14.167^{0}N & 75.0270^{0}E), Shimoga District, Karnataka 17 November 1966	Rajagopalan (1967)
35	*Niviventer niviventer* (Hodgson, 1836) Himalayan White-bellied Rat	A partial albino, white on posterior side while blackish-brown on anterior side of dorsal view, on both lateral side mixed with black and white. No mixing with Domestic Rat hence a pure wild partial albino collected out of eight specimens (image).	Piebaldism (one male)	Partial albinism	Dense, evergreen forest of Khasi Hills, Shillong Peak (25.547^{0}N & 91.875^{0}E), Meghalaya In 1965	Rajagopalan & Mandal (1965)
36	*Rattus norvegicus* (Berkenhont, 1769) Brown Rat or Norway Rat	A piebald (partial albino) rat having two-third body white on posterior side whereas rest of body black on dorsal side, ventral side white. Tail brown on upper side, terminal portion white (image).	Piebaldism (one female)	Piebald albino	Library Road, Dadar, Bombay (19.028^{0}N & 72.839^{0}E), Maharashtra (skin preserved in Haffkine Institute Bombay) 06 February 1960	Joshee & Kamat (1963)
37	*Rattus rattus* (Linnaeus, 1758) Common House Rat	Part albinos, individuals with white belly, rest of the body normal, several in population.	Piebaldism (several)	Part albino	Calcutta (22.580^{0}N & 88.363^{0}E), W.B. In 1907	Hossack (1907)
38	*Rattus rattus*	Part albinos with white belly (recorded by The Plague Investigation Commission in India).	Piebaldism (many)	Part albino	Bombay (19.079^{0}N & 72.879^{0}E), Maharashtra In 1912	Joshee & Kamat (1963)

	Taxa and common name	Description of aberration as given by the original author (with remarks, if any)	Most likely aberration (sex, if any)	Aberration as named by the original author	Locality (with decimal coordinates) and date (if any)	Source
39	*Rattus rattus*	16 part albinos (white belly) out of 682 (examined in rat-flea survey).	Piebaldism (16)	Part albino	Bhandup, Bombay (19.150^{0}N & 72.931^{0}E), Maharashtra August to November 1959	Joshee & Kamat (1963)
40	*Rattus rattus*	The colour of body and tail completely black with no line of demarcation between dorsal and ventral aspects. Pinna lighter in colour.	Melanism (two males and three females)	Melanism	Calcutta (22.580^{0}N & 88.363^{0}E), W.B. (in collection of ZSI, Kolkata) In 1906	Bhattacharyya (1973)
41	*Rattus rattus*	One black rat	Melanism (one)	Melanism	Suburban areas of Bombay (19.156^{0}N & 72.874^{0}E), Maharashtra Before 1961	Joshee (1961)
	Family: Hystricidae					
42	*Hystrix brachyura* Linnaeus, 1758 Himalayan Crestless or Malayan Porcupine	An albino without any pigmentation. Absence of crest bristles on crown. Tail not brush-like.	Undetermined (one sub-adult female)	Albino	28km north of Imphal on Dimapur Road (25.367^{0}N & 93.983^{0}E), Imphal Dist, Manipur (in collection of ZSI, Kolkata. Reg. No. 11349) 29 November 1945	Mandal & Ghosh (2000)
43*	*Hystrix* sp. Porcupine	White	Undetermined	Albino	Nandankanan Biological Park, Odisha	Anonymous (2013 a)
	Order: Erinaceomorpha Family: Erinaceidae					
44	*Paraechinus micropus* (Blyth, 1846) Indian Hedgehog	Total white together with spines, eyes reddish. Seen with a normal individual (image).	Albinism (adult)	Albino	Amali Village (21.628^{0}N & 74.003^{0}E), Akkalkuwa Taluk, Nandurbar District, Maharashtra 08 August 2015	Mahabal et al. (2015)
	Order: Soricomorpha Family: Soricidae					
45	*Suncus murinus* (Linnaeus, 1766) House Shrew	An albino having general colour from pure white to dirty white, naked parts and colour of iris pinkish.	Albinism (one female)	Albinism	Jabalpur City (23.166^{0}N & 79.951^{0}E), M.P. (in collection of ZSI, Jabalpur) 16 October 1975	Khajuria (1983)
	Order: Chiroptera Family: Pteropodidae					
46	*Rousettus leschenaultii* (Desmarest, 1820) Fulvous Fruit Bat or Leschenault's Rousette	Albino but colour details not given.	Undetermined (one)	Albino	-	Karim (1983) cited by Bhati (1988)
	Family: Hipposideridae					
47	*Hipposideros diadema* (*nicobarensis*) (E. Geoffroy, 1813) Diadem Leaf-nosed Bat	In a colony of 500 normal-coloured bats, one single albino with pelage of entire body white, eyes red (image).	Albinism (one male)	Albino	Forest cave at Katchal Island (7.970^{0}N & 93.354^{0}E), Nicobar Archipelago, A.N. In November 2002–2003	Aul & Marimuthu (2006)
48*	*Hipposideros diadema* (*nicobarensis*)	The albino bat was disgorged by a Pit Viper.	Albinism (one dead)	Albino	Forest cave at Katchal Island (7.970 ^{0}N & 93.354^{0}E), Nicobar Archipelago, A.N. In November 2002–2003	Aul & Marimuthu (2006)
49	*Hipposideros lankadiva* Kelaart, 1850 Indian Leaf-nosed Bat	Albino specimen collected along with normal individuals but no other details provided.	Undetermined	Albino	Hoshangabad Dist. (22.666^{0}N & 77.500^{0}E), M.P.	Khajuria (1984)
50	*Hipposideros* sp. Leaf-nosed Bat	Albino from a large colony of bat in a cave, no colour details provided.	Undetermined (one)	Albino	A district in M.P. In 1972	Khajuria (1973)
	Family: Rhinopomatidae					
51	*Rhinopoma hardwickei* (*hardwickei*) Gray, 1831 Lesser Rat-tailed or Lesser Mouse-tailed Bat	General pelage, wing membranes, metacarpels, phalanges, and ears white to dirty white. Legs, arms, tail, face, chin, throat pinkish. Colour of eyes not mentioned. In a bat colony of 100 individuals.	Leucistism (one female)	Albinism	Cave near Jabalpur City (23.152^{0}N & 79.937^{0}E), M.P. (in collection of ZSI, Jabalpur) 26 April 1972	Khajuria (1973)

	Taxa and common name	Description of aberration as given by the original author (with remarks, if any)	Most likely aberration (sex, if any)	Aberration as named by the original author	Locality (with decimal coordinates) and date (if any)	Source
52	*Rhinopoma hardwickei* (*hardwickei*)	-	Piebaldism (three individuals)	Partial albinism	Building	Senacha & Purohit (2005)
53*	*Rhinopoma microphyllum* (=*kinneari* Wroughton) (Brunnich, 1782) Rat-tailed or Greater Mouse-tailed Bat	Albino in a bat colony in the university campus. No other details provided (image).	Albinism (one male)	Albino	University of Jodhpur (26.291⁰N & 73.031⁰E), Jodhpur, Rajasthan During 1987–1988	Bhati (1988)
54	*Rhinopoma microphyllum*	A large colony of about 50,000 individuals in a cave mine, a single white-coloured pink-eyed albino sighted (image).	Albinism (one)	Albino	Sipa Mines (22.406⁰N & 73.618⁰E), border of Jambughoda WS, Gujarat 10 June 2009	Devkar et al. (2011)
	Family: Emballonuridae					
55	*Taphozous* sp. Tomb Bat or Sheath-tailed Bat	A roosting bat colony in fort groove /crevices of wall, a single white-bodied individual having reddish eyes with tinge of orange; mouth, ears and fore-arms orange-red (image).	Albinism (one)	Albino	Red Fort (28.656⁰N & 77.241⁰E), Delhi 20 October 2010	Dhanya et al. (2015)
	Order: Carnivora Family: Felidae					
56	*Catopuma* (=*Pardofelis*) *temminckii* (Vigors & Horsfield, 1827) Asiatic Golden Cat	Black-coloured morph (image).	Melanism (number of individuals)	Melanism	Prek Chu catchment of Khangchendzonga B,R. (27.491⁰N & 88.184⁰E), Sikkim January 2009 to August 2010	Bashir et al. (2011)
57	*Felis chaus* Schreber, 1777 Jungle Cat	Dorsum and underside, limbs including tail dark brown.	Melanism (one)	Melanism	Belgaum (15.868⁰N & 74.500⁰E), Karnataka (in collection of BNHS, Mumbai, Reg. No. 6035). 05 December 1912	Chakraborty et al. (1988)
58	*Felis chaus*	Entire dorsum, tail, limbs with dark brown hairs, sides of body and cheeks with pale cream hairs.	Melanism (one)	Partial melanism	Tikoli (26.308⁰N & 78.109⁰E), 22km from Gwalior, M.P. (in collection of BNHS, Mumbai, Reg. No. 6018) February 1914	Chakraborty et al. (1988)
59	*Felis chaus*	Entire dorsum, under surface, and tail dark brown with some fine pale cream grizzling except in mid-dorsal region	Melanism (one)	Melanism	Arcadia Tea Estate (10.078⁰N & 77.221⁰E), T.N. (in collection of BNHS, Mumbai, Reg. No. 6044) 22 February 1940	Chakraborty et al. (1988)
60*	*Felis chaus*	Pink colour of eyes was not obvious. Observed in camera trap.	Leucism (one)	Partial albinism	Amaravila area (8.390⁰N & 77.098⁰E), Neyattinkara Taluk, Thiruvananthapuram District, Kerala	Sanil et al. (2014)
61*	*Prionailurus bengalensis* Kerr, 1792 Leopard Cat	Two black-coloured individuals in camera trap by WWF.	Melanism (two)	Melanistic	Bonnie Camp, Sunderbans BR, (21.866⁰N & 88.891⁰E), South 24-Paragana Forest Division, W.B. February 2013	Anonymous (2013c)
62	*Acinonyx jubatus* (Schreber) Indian Cheetah	Due to lack of pigmentation of hairs, whitish body inclined to bluishness and light coloured spots also look bluish (instead of black spots) due to body colour. Colour of eyes not mentioned (in the memoirs of Mughal Emperor Jahangir). Only known historic record.	Leucism? (one adult)	White	Orcha (25.279⁰N & 78.616⁰E), M.P. In 1608	Divyabhanusinh (1987b, 1993)
63	*Panthera pardus* (Linnaeus, 1758) Leopard or Panther	Total black-coloured Leopard	Melanism (one)	Black	Calcutta Zoo (22.536⁰N & 88.332⁰E), W.B. In 1889	Buckland (1889)
64	*Panthera pardus*	Black-coloured, known to author.	Melanism (one)	Black	Madras Residency, T.N. In 1889	Buckland (1889)
65	*Panthera pardus*	Uniformly black-coloured pair, deep brown belly with black blotches, normal eyes, palate and pink tongue.	Melanism (one male and one female)	Melanism	Brought from northern China (?) 1902–1903	Ferris (1905, 1906a)

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66	*Panthera pardus*	Progeny of above pair. All black-coloured cubs in two litters.	Melanism (Two and five cubs)	Melanism	Captive breeding at Kolhapur Zoo, Maharashtra (16.719⁰N & 74.232⁰E) 1905–1906	Ferris (1905, 1906a)
67	*Panthera pardus*	Shot black-coloured animal with black tongue.	Melanism (one)	Melanism	Kanara (14.157⁰N & 74.967⁰E), Karnataka In 1905	Ferris (1906a)
68	*Panthera pardus*	Shot black-coloured animal with black tongue.	Melanism (one)	Melanism	Supa (18.336⁰N & 74.372⁰E), Maharashtra In 1905	Ferris (1906a)
69	*Panthera pardus*	Shot animal with very dark brown to black on upperparts, little lighter on ventral parts and limbs. Tongue and mouth pink, eyes and claws normal-coloured.	Melanism (one male)	Black	Dajipur Jungle, (16.425⁰N & 73.996⁰E), Kolhapur District, Maharashtra 12 May 1906	Ferris (1906b)
70	*Panthera pardus*	A black-coloured paired gave birth to six cubs in two litters in captive breeding. All cubs black-coloured.	Melanism (one male and one female adult; three males and three female cubs)	Melanism	Zoological Garden, Calcutta (22.536⁰N & 88.332⁰E), W.B. July 1925 to 1926	Ali (1927)
71	*Panthera pardus*	Black colour with pale blue eyes, caught and transported to Calcutta Zoo.	Melanism (two males and one female)	Black (two males and one female)	Forest of Dannig (26.629⁰N & 91.507⁰E), Assam 05 November 1931	Pizey (1932)
72	*Panthera pardus*	A black-coloured pair gave birth to six cubs in three litters. All cubs black in colour during captive breeding.	Melanism (one male and one female adult; three males and three female cubs)	Black	Jamnagar (22.472⁰N & 70.057⁰E), Gujarat January 1939 to June 1940	Bahadur (1942a)
73	*Panthera pardus*	Shining black-coloured coat with very faint brown spots.	Melanism (one)	Black	Bhaluharcar Cave, Meur Hot Spring, Eastern Kharagpur Forest Range (25.126⁰N & 86.546⁰E), Bihar Between 1990 and 1996	Sinha (1996)
74	*Panthera pardus*	Black in colour	Melanism (one)	Black	Morwe River near Sinhoul Village, West Kharagpur Forest Range (22.333⁰N & 87.294⁰E), Bihar Between 1990 and 1996	Sinha (1996)
75	*Panthera pardus*	Black leopard basking in sun during winter months.	Melanism (one)	Black	Gridhakoot Hill, Kharagpur Forest Range (25.126⁰N & 86.546⁰E), Bihar Between 1990 and 1996	Sinha (1996)
76	*Panthera pardus*	A captive black leopard.	Melanism (one)	Black	Nandankanan Park (20.397⁰N & 85.820⁰E), Orissa Between 1990 and 1996	Sinha (1996)
77	*Panthera pardus*	Black-coloured animal seen in wild state.	Melanism (one male)	Black	Corbett N.P. near Ramnagar (29.436⁰N & 79.129⁰E), Uttarakhand March 1958	Bedi (1998)
78	*Panthera pardus*	Black colour, transported from Assam to Nandankanan Park, Orissa.	Melanism (one male)	Black	Guwahati Aviary (26.146⁰N & 91.735⁰E), Assam 18 October 1972	Bedi (1998)
79	*Panthera pardus*	Black-coloured cubs in captive breeding born to a normal-coloured female and black male.	Melanism (one male and two cubs)	Black	Nandankanan Biological Park (20.397⁰N & 85.820⁰E), Orissa 02 August 1973	Bedi (1998)
80	*Panthera pardus*	Black-coloured.	Melanism (one)	Black	Delhi Zoo (28.601⁰N & 77.244⁰E), Delhi In 1998	Bedi (1998)
81	*Panthera pardus*	Black-coloured with black rosette hidden beneath the black pigmentation in wild state (probably the same individual sighted in different months at same locality; image with editors).	Melanism (one)	Melanism	Kas plateau, part of Western Ghats (17.721⁰N & 73.823⁰E), Satara District, Maharashtra 08 December 2010, 21 March 2012, 13 April 2012	Sayyed et al. (2013)

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82	*Panthera pardus*	Black in colour in hilly areas in wild state.	Melanism (one)	Melanism	Near Manohar Mansantosh Twin Forts (15.897^{0}N & 73.684^{0}E), Western Ghats, Sindhudurg District, Maharashtra. 03 June 2009	Sayyed et al. (2013); Anonymous (2009)
83	*Panthera pardus*	Black-coloured wild leopard sighted by local people and forest department personnel.	Melanism (one)	Melanism	Chandoli NP (17.168^{0}N & 73.771^{0}E), Sangli District, Maharashtra Between 2008 and 2012	Sayyed et al. (2013)
84	*Panthera pardus*	Black-coloured with black rosette (sighted thrice in the same area in wild; image with editors).	Melanism (one)	Melanism	Banks of Bhadra Reservoir in Bhadra TR (13.685^{0}N & 75.641^{0}E), Chickmaglur District, Karnataka 22 February 2012, April 2012, May 2012	Sayyed et al. (2013)
85*	*Panthera pardus*	One or more black leopards caught in camera traps (image by Ulhas Karanth).	Melanism (one or more)	Melanistic	Dandeli WS, (15.247^{0}N & 74.634^{0}E), Karnataka In 2008–2016	Karanth (2014)
86*	*Panthera pardus*	--do--	Melanism	Melanistic	Anshi NP (14.998^{0}N & 74.358^{0}E), Karnataka In 2008–2016	Karanth (2014)
87*	*Panthera pardus*	--do--	Melanism	Melanistic	Bhadra WS (13.446^{0}N & 75.574^{0}E), Karanataka In 2008–2016	Karanth (2014)
88*	*Panthera pardus*	--do--	Melanism	Melanistic	Bandipur NP (11.665^{0}N & 76.628^{0}E), Karnataka In 2008–2016	Karanth (2014)
89*	*Panthera pardus*	--do--	Melanism	Melanistic	Wynaad, Nilgiri BR (11.934^{0}N & 76.004^{0}E), Kerala In 2008–2016	Karanth (2014)
90*	*Panthera pardus*	Personal observations of black leopards by Tariq Badar during his treks and camping in the wild.	Melanism (several)	Melanistic	Shivalik Hills and Terai areas of Uttar Kashi Dist. (30.928^{0}N & 78.475^{0}E), Uttarakhand In 1994–2014	Badar (2014)
91*	*Panthera pardus*	--do--	Melanism (several)	Melanistic	Shivalik Hills and Terai areas of Dehradun Dist. (30.316^{0}N & 78.031^{0}E), Uttarakhand In 1994–2014	Badar (2014)
92*	*Panthera pardus*	--do--	Melanism (several)	Melanistic	Shivalik Hills and Terai areas of Pilibhit Dist. (28.583^{0}N & 80.008^{0}E), Uttarakhand In 1994–2014	Badar (2014)
93	*Panthera pardus*	Fur with dense deposit of melanin, closet black rosettes present but hidden beneath the black pigmentation. A roadkill (image).	Melanism (sub adult male)	Melanism	Mumbai-Bengaluru Highway near Satara City (17.658^{0}N & 74.014^{0}E), Maharashtra 27 March 2015	Sayyed & Mahabal (2015)
94*	*Panthera pardus*	A single black panther.	Melanism (one)	Melanistic	Sanguem (15.230^{0}N & 74.150^{0}E), Goa December 2015	Anonymous (2015)
95	*Panthera pardus*	Skin pale rich buff, spots dull orange, eyes bright sky blue but not pink-coloured. Black hairs at the tip of tail.	Blue-eyed white morph (one female)	Pale-coloured form	Calcutta (22.580^{0}N & 88.363^{0}E), W.B. In 1940–1941	Fooks (1941)
96	*Panthera pardus*	Animal shot had ground pale colour than usual with tan spots.	Hypomelanism (one)	Pale-coloured form	Dumraon State (23.965^{0}N & 85.365^{0}E), Hazaribagh District, Bihar (in British Museum, London) Before 1940	Fooks (1941); Pocock (1939)
97	*Panthera pardus*	A semi-albino was shot, had white body with pale background, rosette in darker shed of tan (image).	Hypomelanism (one)	White/semi-albino	Dumraon State (23.965^{0}N & 85.365^{0}E), Hazaribagh District, Bihar Before 1940	Ingen & Ingen (1941)
98	*Panthera pardus*	Killed animal had light sandalwood colour. Skin exists.	Hypomelanism (one)	Mutant	Jhinna, near Ajaigarh (24.726^{0}N & 80.188^{0}E), Panna District, M.P. In 1905	Divyabhanusinh (1993)

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99	*Panthera pardus*	Shot a white animal with sandalwood-coloured light spots all over the body.	Hypomelanism (one)	Mutant	Aramgang Village, Ajaigarh (24.726⁰N & 80.188⁰E), Panna District, M.P. (mounted trophy in Ajaigarh Palace) In 1965	Divyabhanusinh (1993)
100	*Panthera pardus*	White leopard shot but no other details.	Leucism? (one)	White or mutant	Dumraon (25.549⁰N & 84.150⁰E), Bihar In 1910	Divyabhanusinh (1993)
101	*Panthera pardus*	White leopard shot but no other details.	Leucism? (one)	White or mutant	Dumraon, (25.549⁰N & 84.150⁰E), Bihar In 1927	Divyabhanusinh (1993)
102	*Panthera pardus*	White animal was shot, at sides creamy towards centre with pale brown spots, tail normal. Eyes sky blue (no trace of pink in the eye when shot).	Blue-eyed white morph (one female)	White or mutant	15 miles from Sarasaran near Dumraon (25.549⁰N & 84.150⁰E), Bihar In 1930	Divyabhanusinh (1993)
103	*Panthera pardus*	The ground colour of the skin much paler than usual, almost cream and the pattern tanned.	Hypomelanism (one)	Mutant	Hazaribagh (23.965⁰N & 85.365⁰E), Bihar (in British Museum, London) In 1939	Divyabhanusinh (1993)
104	*Panthera pardus*	White (albino) leopard, but no other details provided.	Albinism? (one)	White or mutant	Not given Before 1907	Divyabhanusinh (1993)
105	*Panthera pardus*	White leopard skin but no other details provided.	Leucism? (one)	White or mutant	Tikamgarh near Orcha (24.974⁰N & 78.928⁰E), M.P. in 1967	Divyabhanusinh (1993)
106	*Panthera pardus*	The skin normal except for having light brown spots instead of black.	Hypomelanism? (one)	Mutant	No information Before 1929	Divyabhanusinh (1993)
107	*Panthera pardus*	Pure white (rare in nature). No other details provided.	Leucism?	White	Hazaribagh (23.965⁰N & 85.365⁰E), Bihar (in British Museum, London)	Bedi (1998)
108	*Panthera tigris* (Linnaeus, 1758) Tiger or Royal Bengal Tiger	Black-coloured animal was killed.	Melanism (one)	Black-coloured	West Bengal In 1889	Buckland (1889)
109	*Panthera tigris*	Total black animal basking on rocks in the evening.	Melanism (one)	Black-coloured	Harrow (9.866⁰N & 77.149⁰E), Cardamom Hills of Travancore, Kerala In autumn of 1895	Capper Stewart (1914)
110	*Panthera tigris*	Very dark coloured animal was shot.	Melanism (one)	Dark coloured	In forest of Central Province In 1912	Pitman (1912)
111	*Panthera tigris*	Animal with very pale yellow skin was shot.	Hypomelanism (one)	Pale yellow colouration	20 miles away from above forest of Central Province In 1912	Pitman (1912)
112	*Panthera tigris*	Black in colour.	Melanism (one)	Black	Lushai Hills, (23.585⁰N & 92.848⁰E), Assam In 1929	Pocock (1929)
113	*Panthera tigris*	A young tiger having dark brown body with black stripes on dark background shot.	Melanism (one)	Melanism	Central Province A few years before 1936	Prater (1937)
114	*Panthera tigris*	Black-coloured animal.	Melanism (one young)	Melanism	Dibrugarh (27.473⁰N & 94.912⁰E), Assam In 1915	Prater (1937)
115	*Panthera tigris*	A black tiger of Royal Bengal type.	Melanism (one)	Black-coloured	Forest in Dibrugarh, (27.473⁰N & 94.912⁰E), Assam 10 October 1936	Prater (1937)
116	*Panthera tigris*	Colour uniformly brown, stripes not visible (to camouflage in the open sandy tracks of Sunderban)	Hypomelanism (one)	Brown variety	Khulana or Backerganj (22.222⁰N & 88.839⁰E), Sunderban, W.B. (from dist. Gazetteer of Bengal)	Prater (1937)
117	*Panthera tigris*	Black skin with tawny stripes on back and white stripes on ventral side. Seen several times by forest officials (animal was shot).	Melanism (one female)	Melanism	Podagad Village, Bhandan River Valley, Similipal TR (21.750⁰N & 86.333⁰E), Orissa July 1993	Prusty & Singh (1996a)
118*	*Panthera tigris*	Black tiger caught in camera trap.	Melanism (one)	Melanistic	Similipal TR, (21.750⁰N & 86.333⁰E), Orissa July 2012	Anonymous (2012a)

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119	*Panthera tigris*	A wild white tigress with two full-grown light fawn cubs all with stripes (depicted in 'Akbar Nama', the earliest record of white tiger in India; image).	Piebaldism? (one adult female and two light fawn cubs)	Mutant or white	Near Gwalior, between Agra and Malwa (26.421^{0}N & 78.850^{0}E), M.P. During Mughal period, in 1561	Divyabhanusinh (1987a)
120	*Panthera tigris*	A wild white tiger skin. No details of stripes and eye colour.	Undetermined (one male)	White	Exhibited in Exeter Change In 1820	Lydekker (1907) cited by Editor BNHS (1910)
121	*Panthera tigris*	Wild white tiger was killed.	Undetermined (one male)	White	Poona (18.522^{0}N & 73.852^{0}E), Maharashtra In 1892	Lydekker (1907) cited by Editor BNHS (1910)
122	*Panthera tigris*	Wild white tiger shot and skin sent to Calcutta. No details of stripe and eye colour.	Undetermined (one male)	White	Upper Assam (26.787^{0}N & 94.213^{0}E) March 1899	Lydekker (1907) cited by Editor BNHS (1910)
123	*Panthera tigris*	Maharaja of Kuch Behar possesses a white tiger skin.	Undetermined (one male)	White	Kuch Behar (26.468^{0}N & 89.645^{0}E), Assam, Before 1907	Lydekker (1907) cited by Editor BNHS (1910)
124	*Panthera tigris*	Wild white tigress was shot having ground colour pure white, stripes deep reddish-black coloured.	Undetermined (one female)	White	Mulin Sub-division Forest of Dhenkand, (20.680^{0}N & 85.574^{0}E), Orissa May 1909	Lydekker (1907) Cited by Editor BNHS (1910)
125	*Panthera tigris*	Albino wild tiger was shot having cream-coloured skin throughout but paler on head, stripes chocolate brown, whiskers dark brown and white.	Hypomelanism (one)	Albino	Pendra Zamindari (22.767^{0}N & 81.458^{0}E), Bilaspur District, M.P. (specimen in Central Museum, Nagpur, Maharashtra) In 1910	D'Abreu (1916)
126*	*Panthera tigris*	A family party of four wild tigers was shot, two of which were normal-coloured adult male and female having two pure full-grown albino cubs with pink eyes (never seen such albinos by many shikaris).	Albinism (one male cub and one female cub)	Pure albino	18 miles in jungles of Cooch Behar (26.358^{0}N & 89.631^{0}E), Assam 08 May 1922	Narayan (1922), also cited by Gee (1959)
127	*Panthera tigris*	Number of pure white and cream-coloured wild tigers with black stripes, normal-coloured eyes but not albino. Either shot or seen by shikaris.	Piebaldism? (number of males and females)	White	Jungles of Bhagalpur District, (25.3478, 86.9822"E), Central Province (now Bihar) Before and in 1926	Robinson (1928)
128	*Panthera tigris*	A wild white tigress with stripes in darker shade of tan, black stripes at tip of tail.	Leucism? (one female)	White	Assam Before 1941	van Ingen & van Ingen (1941)
129	*Panthera tigris*	Number of pure white wild tigers with light black stripes, eyes with black pupil, nose grey-pink. Either shot or captured.	Leucism (number of males and females)	White	Jungles and hill ranges of Rewa State, forested areas of Bilaspur and Mandla districts, Sidhi Dist, Central Province (now M.P.) Between 1950 and 1951	Oswald (1960), also cited by Singh (1996)
130	*Panthera tigris*	A white tiger cub with dark-chocolate stripes on orange-red skin and 'ice- blue eyes' was caught and reared in Govindgarh Palace and named 'Mohan'.	Blue-eyed white morph (one male)	White (male cub	Bartari Forest, Yadwas RF, Sidhi District, M.P. 28 May 1951	Oswald (1960)
131	*Panthera tigris*	Number of wild white tigers shot.	Undetermined (number of males and females)	White	Forests of Assam, Meghalaya, Odisha, West Bengal, Bihar, M.P. & Maharashtra Between 1907 and 1958	Sankhala (1969, 1978), also cited by Sinha (1993)
132	*Panthera tigris*	A sub-adult tiger (eyes look normal-coloured in image).	Leucism (a single likely sub-adult, age and sex unknown)	Pale	Nilgiri BR, Tamil Nadu June/ July 2017 by Nalanjan Ray	Anonymous (2017a,b,c)
	Family: Viverridae					
133*	*Paradoxurus hermaphroditus* (Pallas, 1777) Common Palm Civet	Total white albino and no trace of black colour on its fur (no description of eyes given). Many Bhils also noticed this adult earlier.	Albinism (one adult)	Albino	Arjunapura Village, Phulwari WS (24.568^{0}N & 73.683^{0}E), Udaipur District, Rajasthan 13 April 2001	Sharma (2004)

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134	*Paradoxurus hermaphroditus*	White body without any black or grey markings, ears and snout pinkish, eyes reddish visible in image (image by Ayan Banerjee)	Albinism (one)	Albino	Kuldina WS (21.199⁰N & 86.299⁰E), Odisha 28 December 2013	Anonymous (2016b)
135	*Paradoxurus hermaphroditus*	Brownish-black coat colour on dorsal side, whitish under fur anteriorly, along with pinkish leg extremities (lack of black pigmentation). Half of the tail white while rest black.	Piebaldism (female)	Colour variant	Roadside Dandeli-Anshi TR (15.272⁰N & 74.535⁰E), Uttara Kannada District, Karnataka 02 July 2015	Chunekar et al. (2017)
136	*Paradoxurus hermaphroditus*	Same features as above.	Piebaldism (juvenile)	Colour variant	Kas Plateau (17.715⁰N & 73.798⁰E), Satara District, Maharashtra 01 November 2015	Chunekar et al. (2017)
137	*Paradoxurus jerdoni* Blanford, 1885 Common Jerdon's or Brown Palm Civet	A white-coloured albino civet (image by Chunekar & Bhat).	Albinism (one)	Albino	Amboli (15.962⁰N & 73.997⁰E; Western Ghats), Siidhudurg District, Maharashtra October 2013	Anonymous (2013b)
	Family: Herpestidae					
138*	*Herpestes edwardsii* (E. Geoffroy Saint-Hilaire, 1818) Indian or Common Grey Mongoose	Mother snow white in colour, with three normal-coloured young ones. Eye colour not mentioned (image).	Undetermined	Albino	Kallarwas Village (24.574⁰N & 73.604⁰E), 15km from Udaipur, Rajasthan 13 March 1993 and again in April 1993	Tehsin & Chawra (1994)
139	*Herpestes smithii* Gray, 1837 Indian Ruddy Mongoose	Total white-coloured wild albino mongoose with pinkish snout and red eyes (images by Raghunandan Kulkarni & Aditya Singh).	Albinism (one adult)	Total albinism	Ranthambore NP (26.017⁰N & 76.502⁰E), Rajasthan 31 May 2009, December 2009, January 2012	Anonymous (2012b); Kulkarni & Mahabal (2014)
	Family: Canidae					
140	*Canis aureus* Linnaeus, 1758 Asiatic (or Golden) Jackal	Black Jackal (shot).	Melanism (one)	Black-coloured	Honavar (14.283⁰N & 74.450⁰E), Kanara District, Karnataka 19 April 1924	Tuggerse (1925)
141	*Canis aureus*	Jet black adult male with thin white stripe down at the centre of chest and a normal adult female having three offspring of which one black a replica of adult.	Melanism (a male, female and a cub)	Black	Island of Dharmadam (11.753⁰N & 75.495⁰E), Tellicherry, Kerala October 1968 to April 1969	Neelakanthan (1969)
142	*Canis aureus*	Remaining two offspring of above pair (one fawn with white under parts and little black on tail, second one a mixture of grey-brown with terminal half of tail black).	Hypomelanism (one cub each)	Fawn and grey-brown coloured	As above	Neelakanthan (1969)
143*	*Canis aureus*	A completely black-coloured individual (image by Pramod Dhal).	Melanism (adult)	Melanistic	Ettikulam in Ezhimala Hill range, Kannur Dist. (12.014⁰N & 75.205⁰E), Kerala	Parida (2014)
144*	*Canis aureus*	Red colour of eyes was not obvious. Two observed in the eight camera trap images of jackals.	Leucism? (two individuals)	Partial albinism	Pulloni mangrove area, near Mangalam Dam, Bhagavathikavu (10.859⁰N & 75.925⁰E), Tirur Taluk, Mallapuram District, Kerala	Sanil et al. (2014)
145*	*Canis aureus*	Red colour of eyes was not obvious. Two albinos in the 12 jackal images, captured in camera traps.	Leucism? (two individuals)	Partial albinism	Near Chaliyam mangroves area (11.1573⁰N & 75.811⁰E), Kozhikode District, Kerala	Sanil et al. (2014)
146	*Canis lupus* (*pallipes*) Linnaeus, 1758 Indian Wolf	Total black-coloured animal with white patch on upper jaw and lower part of the chest, tail black (image).	Melanism (one)	Melanism	Agricultural field c. 5km southeast of Mangalwedha (17.500⁰N & 75.433⁰E), Solapur District, Maharashtra 26 September 2012	Lokhande & Bajaru (2013)
147	*Cuon alpinus* (Pallas, 1811) Wild Dog or Dhole	Total black except a white tip at tail.	Melanism (one)	Complete melanism	Gaddesal in northern Coimbatore Forest Division (11.136⁰N & 76.976⁰E), T.N. 11 January 1936	Morris (1936a)

	Taxa and common name	Description of aberration as given by the original author (with remarks, if any)	Most likely aberration (sex, if any)	Aberration as named by the original author	Locality (with decimal coordinates) and date (if any)	Source
	Family: Ursidae					
148	*Melursus ursinus* (=*Ursus labiatus*) (Shaw, 1791) Sloth Bear	One cub was shot, skin thick, shaggy, tawny-brown throughout, light-coloured underneath, whitish collar on chest but no black colour anywhere.	Hypomelanism (one cub)	Colour variant	Jungles of Midnapore, (22.422^{0}N & 87.325^{0}E), W.B. November 1884	Sterndale (1886)
149	*Melursus ursinus*	It was shot, only hind quarters of body grey.	Hypomelanism (one)	Colour variant	Secunderabad (17.440^{0}N & 78.499^{0}E), Deccan, A.P. March 1886	Sterndale (1886) (from "Asian sporting" newspaper)
150	*Melursus ursinus*	It was shot, body grey to light grey; native shikaris called it 'safed bhalu'.	Hypomelanism (one)	Colour variant	Borders of Shahabad (25.770^{0}N & 81.399^{0}E), Mirzapur District, U.P. March 1886	Sterndale (1886) (from "Asian sporting" newspaper)
151	*Melursus ursinus*	Shot a sloth bear with two cubs—one was brown instead of black. Other cub normal black.	Hypomelanism (one cub)	Colour variant	Not mentioned 09 March 1886	Sterndale (1886) (from "Asian sporting" newspaper)
152	*Melursus ursinus*	It was shot. Uniformly brown in colour with grey snout, eyes blue and not brown, iris and pupil deep blue.	Hypomelanism (one)	Brown-variety	Sandy nalla in jungles of HazariBagh (24.131^{0}N & 85.468^{0}E), Bihar In 1914	Saunders (1914)
153	*Melursus ursinus*	Shikaris saw two sloth bears, one normal black and other one red-brown.	Hypomelanism (one)	Red-brown variety	Jungles of Orissa (17.740^{0}N & 81.948^{0}E) In 1914	Saunders (1914)
154	*Melursus ursinus*	A bear was shot having light golden brown long and thick hairs accompanied by other normal black-coloured bear.	Hypomelanism (one male)	Brown-variety	Rajpur (21.260^{0}N & 81.635^{0}E), Central Province Before 1929	Duke (1929)
155	*Melursus ursinus*	Author knows about another such specimen of similar light golden brown bear.	Hypomelanism (one)	Brown-variety	Not mentioned Before 1929	Duke (1929)
156	*Melursus ursinus*	A white-coloured adult male seen by tribals, possibly the father of three white cubs mentioned below.	Albinism (one male)	Albino	Madkote Village, Marwahi Block (22.5039, 81.7800), near Achanakamar WS, Bilaspur District, M.P. In 1988	Bharos (1988)
157*	*Melursus ursinus*	Three white cubs, completely white with pink eyes, snout and upper muzzle portion light pink. V-mark on chest difficult to distinguish. Mother normal-coloured.	Albinism (one female and two unsexed cubs)	Albino	Madkote Village, Marwahi Block (22.503^{0}N & 81.780^{0}E), near Achanakamar WS, Bilaspur District, M.P. In 1988	Bharos (1988)
158	*Ursus thibetinus* G [Baron] Cuvier, 1823 Himalayan or Asian Black Bear	Author knows about several cinnamon-coloured variety of sloth bears (not uncommon).	Hypomelanism (several individuals)	Brown form	Not mentioned Before 1940	van Ingen (1941)
159	*Ursus thibetinus*	One bear with cinnamon colour.	Hypomelanism (one male)	Brown form	In the Zoo of H.H. Maharaja of Dewas (22.960^{0}N & 76.059^{0}E), M.P. Before 1941	van Ingen (1941)
	Order: Artiodactyla **Family: Suidae**					
160*	*Sus scrofa* Linnaeus, 1758 Wild Boar or Wild Pig	Shot white albino boar having completely white hairs; nose, eyes, and hoofs pink in colour (attacking nature, possess harem).	Albinism (one male)	Albino	45 miles from Udaipur (24.839^{0}N & 73.583^{0}E), Rajasthan 27 May 1946	Sinha (1946)
161	*Sus scrofa*	Spotted big albino boar, completely white (image).	Albinism (one adult male)	Albino	Daroji Sloth Bear Sanctuary (15.394^{0}N & 76.813^{0}E), Hospet, Bellary District, Karnataka November 2004	Neginhal (2005)
	Family: Cervidae					
162	*Axis axis* (Erxleben, 1777) Spotted Deer or Chital	Total white deer, an albino, brought for experimental purpose.	Albinism (one male adult)	Albinism	Crawford Market for sell in Bombay, Maharashtra In 1942	Bahadur (1942b), also cited by Taibal (1945)

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163*	*Axis axis*	An albino chital shot; it was snow white, eyes and hoofs pink, faint silky white spots (image).	Albinism (one female)	Albino	Doon (now Dehradun) (30.318^{0}N & 78.032^{0}E), Uttarakhand November 1931	Atkinson (1932)
164*	*Axis axis*	Total albino with red-coloured eyes, bred in zoo.	Albinism (one adult)	Albinism	Ahmedabad Zoo (23.011^{0}N & 72.600^{0}E), Gujarat Before 1986	Smielowski (1987); Anonymous (1986)
165	*Axis axis*	In a herd of 24 Chital on a hillock, a single pure white individual with pink eyes and ears (image).	Albinism (one young female)	Albino	Ramganga, Palain River in Corbett TR (29.432^{0}N & 79.128^{0}E), Uttarakhand 20 August 1995	Singh Brijendra (1996)
166*	*Axis axis*	No details.	Undetermined	Albino	Sonanadi WS (29.594^{0}N & 78.744^{0}E), Nainital District, Uttarakhand	Anonymous (undated) as cited by Singh (2014)
167*	*Axis axis*	No details.	Undetermined (two adults)	Alibino	Panvel Zoo, Raigad District, Maharashtra	Dey (2000)
168*	*Axis axis*	White.	Undetermined (fawn)	Albino	Nagarhole, (11.955^{0}N & 76.038^{0}E), Karnataka	Panda (2009)
169*	*Axis axis*	White-bodied male Chital without pinkish colour on nasal region and eye (image by S.G. Neginhal)	Leucism (one adult male)	White	Nagarhole NP (12.041^{0}N & 76.131^{0}E), Karnataka In 2008	Anonymous (2008a)
170*	*Axis axis*	White Chital born in zoo with dark eyes and dark nose.	Leucism (one fawn)	White	Ahmedabad Zoo (23.011^{0}N & 72.600^{0}E), Gujarat April 2010	Anonymous (2010a)
171	*Axis axis*	White-bodied with dark eyes and nostrils (image).	Leucism (one female)	White	Ranthambore NP (26.017^{0}N & 76.502^{0}E), Rajasthan 08 March 2012	Parashar (2012a)
172	*Axis axis*	White-bodied calf (image).	Leucism (one young)	White	Ranthambore NP (26.017^{0}N & 76.502^{0}E), Rajasthan 29 July 2012	Parashar (2012b)
173*	*Axis axis*	White-bodied female and a fawn having pinkish nose (image).	Albinism (one female and one fawn)	Albino	Piplideh, Anantpura Chawki, Kundera Range, Ranathambhore TR (26.017^{0}N & 76.502^{0}E), Rajasthan 12 January 2012	Prabhu et al. (2013)
174*	*Axis axis*	Albino Chital.	Albinism? (one)	Albino	Jamshedpur Zoological Park (22.817^{0}N & 86.199^{0}E), Jharkhand	Mohan (2014)
175*	*Axis axis*		Albinism? (one)	Albino	Katerniyaghat WS (28.000^{0}N & 81.200^{0}E), near Bahraich, U.P.	Dasgupta (2014); Mishra (2014)
176*	*Axis axis*	In a normal-coloured herd of 13 Chital a snow white fawn with few faint creamy spots visible on body with pink-coloured eyes, nasal tip, and ears; white hairs on eyebrows (images).	Albinism (fawn)	Albino	Kantarsingh, Labangi section of Pampasar Forest Range, Satkosia TR (20.525^{0}N & 84.793^{0}E), Odisha 05 June 2014	Pradhan et al. (2014)
177	*Axis axis*	Total white with reddish eyes (image).	Albinism (fawn with adult)	Albino	Pench NP (22.033^{0}N & 79.829^{0}E), M.P. 23 January 2015	Sayyed et al. (2015 b)
178	*Axis axis*	A jet black coat coloured with typical spots of spotted deer hidden under the coat, in a herd of normal-coloured wild deer (image with editor).	Melanism (one adult)	Melanism	Reservoir in Parambikulam TR (10.393^{0}N & 76.775^{0}E), Kerala July 2009	Kumar (2012)
179	*Axis axis*	A blackish deer in a herd of normal deer whose antlers had rounded outgrowths (image).	Melanism (male)	Melanism	Muthanga Forest Range (11.709^{0}N & 76.069^{0}E), Wayanad WS, Kerala 14 January 2014	Anwar et al. (2015)
180	*Axis axis*	Pelage blackish to dark brown in a herd (image).	Hypomelanism (male)	Melanism	2km away from the above location on same date	Anwar et al. (2015)

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181*	*Axis axis*	White pelage with reddish eye seen in image (images by Rishiraj Deval & Manoj Parashar).	Albinism (female)	Albino	Ranthambore NP (26.017°N & 76.502°E), Rajasthan December 2008 & May 2011	Anonymous (2008b, 2012c)
182*	*Axis axis*	A white fawn with white pelage and pinkish eye seen in the image (image by Prabheer Patil).	Albinism (fawn)	Albino	Pench NP (21.762°N & 79.338°E), M.P. February 2007	Anonymous (2010b)
183*	*Axis porcinus* (Zimmerman, 1780) Hog Deer	Shot a full-grown female, white all over the body with hoofs and eyes pink, hence true albino (Shikaris had not seen such a white deer for the last 45 years). First record from India.	Albinism (one female)	True Albino	Cooch Behar State (26.468°N & 89.645°E), Assam In 1916	Adamson (1916)
184*	*Muntiacus muntjak* (Zimmermann, 1780) Indian Muntjak or Barking Deer or Red Muntjak	A total white Muntjac was sighted.	Undetermined (one adult)	White	Mutta (14.304°N & 74.530°E), thick forested area of southern India 25 August 1906	Charrington (1907)
185	*Muntiacus muntjak*	Very dark brown and nearly black Barking Deers reported commonly.	Melanism (many)	Melanism	Forest of Darjiling Dist. (27.046°N & 88.245°E), W.B., (one such mounted in Darjiling Natural History Museum). In 1952	Inglis (1952)
186*	*Muntiacus muntjak*	An image of albino deer shot by Raja Chandra Chud Prasad Singh of Udaipur.	Albinism (one)	Albino	Udaipur (24.603°N & 73.701°E), Rajasthan February 1959	Cited by Editor BNHS (1959)
187	*Muntiacus muntjak*	Conspicuous white spots above the hoofs.	Piebaldism (one young)	"White spots"	Shencottah, taken to Madumalai WS (11.575°N & 76.621°E), Udhagamandalam, T.N. In 1982	Johnsingh (1984)
188	*Muntiacus muntjak*	Dark-coloured.	Melanism (adult)	Melanism	Senchal WS (26.993°N & 88.265°E), Darjeeling District, W.B.	Sunar et al. (2012), cited by Choudhury (2014)
189	*Muntiacus muntjak*	Dark-coloured coat (sighted by Forest Department).	Melanism (two adults of which one injured)	Melanism	Kitam Bird Sanctuary (27.107°N & 88.350°E), Wildlife Wing, Namchi, Sikkim October 2013	Cited by Choudhury (2014)
190	*Muntiacus muntjak*	Dark brownish-grey.	Hypomelanism (adult)	Melanism	Legship (27.266°N & 88.266°E) near Pelling, West Sikkim, 15 June 2014	Choudhury (2014)
191*	*Rusa unicolor* (Kerr, 1792) Sambar	A white-albino Sambar, completely pigmentless, eyes and muzzle conspicuously pink, ears light pigmented, all hair on body white (in mixed forest of Sal and Chir).	Albinism (one adult)	Albino	1,500ft near Chaukhamb Hills of Kohtri Valley (29.380°N & 79.463°E), Landowne, Nainital District, Uttarakhand In 1938	Champion (1938)
192*	*Rusa unicolor*	In a herd of three, single white female with other two normal-coloured (first time seen albino).	Undetermined (one female)	Albino	Gunaithittu, Talamalai range (11.112°N & 76.892°E), North Coimbatore, T. N. May 1951	Pillay (1953)
193	*Rusa unicolor*	In a herd of six, one stag complete white other normal-coloured hinds (Shikaris have seen this herd number of times).	Undetermined (one male)	Albino	Gunaithittu, Talamalai Range (11.112°N & 76.892°E), northern Coimbatore, T.N. November 1951	Pillay (1953)
194*	*Rusa unicolor*	A young albino female caught and died later on in captivity (image shows normal-coloured eyes).	Leucism (one young female)	Albino	Near Jaisamand Lake & Forest (24.239°N & 73.959°E), 50km from Udaipur, Rajasthan (exhibited in City Palace Archaeological Museum, Udaipur) Before 1947	Tehsin (2006, 2012)

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195*	*Rusa unicolor*	A birth of white-coloured fawn in Zoo Garden.	Undetermined (fawn)	White	Manipur Zoological Garden (24.817^{0}N & 93.890^{0}E), Iroishemba, Manipur 23 March 2010	Anonymous (2010c), cited by Pande et al. (2010)
196*	*Rusa unicolor*	A pure white albino with reddish snout and red eyes, inside of ears pinkish (image).	Albinism (one fawn)	Albino	Jamunagawd beat of Jhirna Range, core area of Corbett NP (29.504^{0}N & 78.830^{0}E), Uttarakhand 19 June 2010	Pande et al. (2010)
197	*Rusa unicolor*	Total white young with pinkish ears in a company of two normal adults (image by S.P. Bharath Kumar).	Albinism (fawn)	Albino	Bandipur TR (11.667^{0}N & 76.632^{0}E), Karnataka 12 October 2014	Anonymous (2016c)
	Family: Bovidae					
198	*Antilope cervicapra* (Linnaeus, 1758) Blackbuck or Indian Antelope	A dark-coloured throughout the body without usual white belly and legs (image).	Melanism (one adult male)	Melanism	Bhopal (23.261^{0}N & 77.412^{0}E), M.P. 06 September 1904	Smith (1905)
199	*Antilope cervicapra*	Brought a white albino for mating experiment but died.	Undetermined (one adult)	Albinism	Forest of Jaipur (26.928^{0}N & 75.864^{0}E), Rajasthan In 1942	Bahadur (1942 b)
200	*Antilope cervicapra*	Total albino with red eyes.	Albinism (one adult)	Albinism	Ahmedabad Zoo (23.011^{0}N & 72.600^{0}E), Gujarat Before 1986	Smielowski (1987)
201	*Antilope cervicapra*	Totally white single individual with normal eye seen in the image (images by Rajal Thaker).	Leucism (one adult)	Leucistic?/ Albinism	Outskirts of Ahmedabad (23.011^{0}N & 72.600^{0}E), Gujarat October 2009 & 27 December 2013	Anonymous (2011a)
202	*Antilope cervicapra*	A white-coloured Blackbuck seen by Mughal Emperor Jahangir.	Undetermined (one)	White	Central India From 1605 to 1627	Divyabhanusinh (1987b)
203	*Antilope cervicapra*	Total white body with normal eyes in a normal-coloured herd of 10 (image by Ajay Parmar).	Leucism (female)	Albino	Velavadar Blackbuck NP (22.044^{0}N & 72.020^{0}E), Gujarat 08 January 2016	Anonymous (2016d)
204*	*Antilope cervicapra*	A white-coloured fawn with normal-coloured eye seen in image (image by Jagadip Singh).	Leucism (fawn)	Albino	Velavadar Blackbuck NP (22.044^{0}N & 72.020^{0}E), Gujarat 09 April 2016	Anonymous (2016e)
205*	*Antilope cervicapra*	A white-coloured adult with normal-coloured eyes seen in the image (images by M.N. Jayakumar & Tejas Soni).	Leucism (male)	Albino/ Leucistic	Velavadar Blackbuck NP (22.044^{0}N & 72.020^{0}E), Gujarat April 2008 & 13 June 2012	Anonymous (2008c, 2012d)
206*	*Antilope cervicapra*	A white-coloured adult with normal eyes seen in multiple photographs of this individual. (Photographs by Mymoonmoghul, Sreelal TS, & Vinod Velu)	Leucism (male)	Albino	Guindy N.P./IIT Madras (13.001^{0}N & 80.233^{0}E), Tamil Nadu 29 April 2010, 14 January 2011 & 06 March 2011	Anonymous (2010d, 2011b, c).
207*	*Antilope cervicapra*	A white-coloured adult with normal eye and black coloured snout seen in the image (image by Ghanashyam Sarvaiya).	Leucism (male)	Albino	Kanjari (22.614^{0}N & 72.915^{0}E), Gujarat October 2015	Anonymous (2016f)
208	*Gazella bennettii* (Sykes, 1830–31) Indian Gazelle or Chinkara	A white-coloured Chinkara seen by Mughal Emperor Jahangir.	Undetermined (one)	White	Central India Between 1605 and 1627	Divyabhanusinh (1987b)
209	*Gazella bennettii*	Brought a total white (albino) for experimental purpose but died.	Undetermined (one adult)	Albinism	Dhrangadra (22.979^{0}N & 71.470^{0}E), Gujarat In 1942	Bahadur (1942b)
210	*Gazella bennettii*	Total white body with red eyes.	Albinism (one adult)	Albinism	Ahmedabad Zoo (23.011^{0}N & 72.600^{0}E), Gujarat Before 1986	Smielowski (1987)
211	*Gazella bennettii*	An albino individual observed by S.M. Mohnot.	Undetermined (one)	Albinism	Dhava-Doli wildlife closed area near Jodhpur, Rajasthan In 2006	Mehra et al. (2010)

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212*	*Bos gaurus* H. Smith, 1827 Gaur	One male, one cow, and a cow with calf in three different herds, sandy or light fawn coloured body. Horns yellow-white with pink base.	Hypomelanism (one adult male, one female, and one female with young one)	White	Munnar Ghat crossing, (10.102⁰N & 77.117⁰E), Pambur River, forest of Coimbatore, T.N. 12 October 1932	Morris (1933)
213	*Bos gaurus*	White bison seen by others in this area.	Undetermined (one adult)	White	Further east of Munnar Ghat area in Kukkual Block (9.963⁰N & 77.410⁰E), T.N. In 1932	Morris (1933)
214	*Bos gaurus*	Occurrence of white bison (image).	Undetermined (one adult)	White	Southern Coimbatore (10.980⁰N & 76.972⁰E), T.N. Before 1935	Morris (1935)
215*	*Bos gaurus*	Controversy over light sandy or fawn coloured or 'dormouse' coloured white bison.	Hypomelanism (one adult)	White or light cream coloured	Chanda Dist. (20.209⁰N & 79.560⁰E"E; now Chandrapur, Maharashtra), Central Province Before 1935	Dunbar Brander (1933, 1935, 1936); Morris (1934, 1936b)
216	*Bos gaurus*	A white bison with no description.	Undetermined (one adult)	White	Kambu Forest Rest House, southern Coimbatore (10.980⁰N & 76.972⁰E), T.N. In 1930	Williams (1936)
217	*Bos gaurus*	A white bison with no description.	Undetermined (one adult)	White	Kodaikanal Hills (10.238⁰N & 77.489⁰E), Madurai District, T.N. In 1930	Williams (1936)
218	*Bos gaurus*	In a herd of 120 bisons and many other smaller herds, there were light-coloured bisons in most herds with varying colour from light red through duns.	Hypomelanism (few)	Light red and light coloured	River at Manjampatti tracks of Kilanavayal, (10.200⁰N & 77.500⁰E), Kodi Hills, Kukkal & Talanji area, Palni Hills Madurai District, T.N. Between 1929 and 1937	Williams (1969)
219	*Bos gaurus*	One herd of 20 bisons in which every animal was abnormal coloured.	Hypomelanism (20)	Abnormal coloured	--do--	Williams (1969)
220	*Bos gaurus*	Full grown white bulls and a cow known to author.	Undetermined (two males and female)	Pure white	--do--	Williams (1969)
221	*Bos gaurus*	All ash-coloured bisons.	Hypomelanism (four)	Ashy-coloured	Amaravathi Nagar (13.079⁰N & 80.204⁰E), southern India In 1965	Davidar (1970)
222	*Bos gaurus*	In two different herds, four and one respectively, were greenish grey and rest normal in colour.	Hypomelanism (five)	Greenish-grey-coloured	Udumal-Kamanuthu Munnar Ghat Road (10.077⁰N & 77.136⁰E), Kerala Before 1970	Davidar (1970)
223	*Bos gaurus*	Cattle keepers saw thousands of bisons but noticed only one strange (grey) coloured bison.	Hypomelanism (one)	Grey coloured	Kumulampatti (11.592⁰N & 76.576⁰E), Northern Slopes of ManjaMalai and MudianMalai, T.N. January 1969	Davidar (1970)
224	*Bos gaurus*	H.H. The Raja of Pudu Kottai saw seven white bisons in thirty years of his observations.	Undetermined (seven)	White	Koilan Alai (10.186⁰N & 77.534⁰E), near Palni Hills, Coimbatore, T.N Between 1940 and 1970	Davidar (1970)
225	*Bos gaurus*	Out of 111 bisons in seven different herds, one young cow with reddish-brown coloured and two light-coloured young ones were observed.	Hypomelanism (two young ones and a young cow)	Light-coloured	Mudian Malai Slope (11.545⁰N & 76.535⁰E), T.N. 1969–1970	Davidar (1970)
226	*Bos gaurus*	In a herd, one bull and four cows of which one young cow was rich chestnut in colour.	Hypomelanism (one female and a young one)	Chestnut coloured	Northern slopes of ManjaMalai and MudianMalai forests (11.613⁰N & 76.575⁰E), T.N. 1969–1970	Davidar (1970)
227	*Bos gaurus*	Head of white cow mounted, pelage almost cream-coloured.	Hypomelanism (one female)	White	Talanji area of Palni Hills (10.173⁰N & 77.478⁰E), T.N. (kept in High Range Club in Munnar, Kerala) Before 1939	Gouldsbury (1971)

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228	*Bos gaurus*	In a herd of 11, four were normal-coloured, two were greyish-white, and remaining five were ranging from brick red to light red.	Hypomelanism (seven)	Greyish-white to light red-coloured	Cheevaparamala Slopes, Chinnar WS (10.306^{0}N & 77.206^{0}E), Idukki District, Kerala (contiguous with Majampatti Valley) 21 October 1997	Ajith et al. (1998)
229	*Bos gaurus*	In a herd of six, one was greyish-white juvenile, three were brick red to light red in colour and two were normal black bulls.	Hypomelanism (four)	Greyish-white to light red coloured	Koottar (9.778^{0}N & 77.208^{0}E), Idduki, Kerala 3 January,1998	Ajith et al. (1998)
230	*Bos gaurus*	Entirely snow white calf in a herd near a salt-lick has faint eyes (image).	Albinism (one)	Albino	Chikkapala Road, Nagarhole NP (12.041^{0}N & 76.131^{0}E), Kodagu District, Karnataka 11 April 2001	Neginhal (2002)
231*	*Bos gaurus*	Mostly fawn-coloured fur on dorsal part with darker brownish below (image by Prabheer Patil).	Hypomelanism (sub-adult)	Albino	Madhai in Satpuda NP (22.558^{0}N & 78.092^{0}E), M.P. April 2007	Anonymous (2010e)
232	*Bos grunniens* Linnaeus, 1766 Yak	Absolute white fur with normal eyes (tamed animal being used for tourism).	Leucism (one adult)	Leucistic	Kufri (31.097^{0}N & 77.267^{0}E), Shimla District, H.P. In 1991	Personal observation by author (AM)
233	*Boselaphus tragocamelus* (Pallas, 1766) Blue Bull or Nilgai	Shot a fawnish white-albino Nilgai having orangish mane and tassel (image).	Hypomelanism (one adult male)	Albino	Palitana (21.527^{0}N & 71.820^{0}E), Kathiawad, Gujarat In 1940	Trivedi (1941)
234	*Boselaphus tragocamelus*	White spots all over the body including neck, trunk, buttock, and shoulder. Numerous tiny spots on head and both limbs. No change in pattern of white spots over the years despite annual moulting. Next generation normal-coloured.	Piebaldism (one adult female)	Albinism	Probably Indian origin (from Amsterdam Zoo taken to Plock Zoo for breeding) November 1975 to April 1979	Smielowski (1987)
235	*Boselaphus tragocamelus*	A young male uniformly off- white. Eyes normal, accompanied by normal coloured Nilgai.	Leucism (one young male)	Unusual colouration	Kalighati (27.328^{0}N & 76.433^{0}E),Sariska NP, Rajasthan In 1986	Ranjitsinh (1987)
236*	*Boselaphus tragocamelus*	A normal-coloured with streak of white colouration from forehead to nostrils, lateral marking from eye to eye. Bare skin around nostrils cream-coloured.	Piebaldism (one adult female)	Unusual colouration	Kalighati (27.328^{0}N & 76.433^{0}E), Sariska NP, Rajasthan In 1986	Ranjitsinh (1987)
237	*Bubalus arnee* Kerr, 1792) Wild Buffalo	Claimed as albino but eyes were normal.	Leucism (one adult)	Albino ?	Probably in Cooch Behar (26.468^{0}N & 89.645^{0}E), Assam In 1916	Adamson (1916)
238	*Tetracerus quadricornis* (de Blainville, 1816) Four-horned Antelope	Shot a pair in which female was total black in colour. Male with normal colour.	Melanism (one female)	Melanism	14 miles from capital of Ambikapur (23.118^{0}N & 83.195^{0}E), Surguja State, Central Province (now Chattisgarh) In 1932	Ramanju of Surguja (1932)
239	*Naemorhedus goral* (Hardwicke, 1825) Himalayan Goral	A pair of albino gorals having white coat, multiplied to six in next 10 years (no other details).	Undetermined (one male and one female and six young ones)	Albino	Chanju Perganah (7,200ft) (32.553^{0}N & 76.126^{0}E), Chamba State (now H.P.) From 1916 to December 1926	Ram Singh Raja (1927)

* indicates the records also quoted by Singh (2014).
Abbreviations: A.N.=Andaman & Nicobar Islands; A.P.=Andhra Pradesh; BNHS=Bombay Natural History Society; Bombay=now Mumbai; BR=biosphere reserve; Calcutta=now Kolkata; Dist.=district; H.P.=Himachal Pradesh; M.P.=Madhya Pradesh; NP=National Park; T.N.= Tamil Nadu; TR=Tiger Reserve; U.P.=Uttar Pradesh; W.B.=West Bengal; WS=wildlife sanctuary; ZMB=Zoologisches Museum des Humboldt-Universitat, Berlin; ZSI=Zoological Survey of India.

Table 3. Family-wise distribution of mammalian species (Pradhan & Talmale 2012) and aberrant colour species recorded in Indian mammals.

					Number of instances in various colour aberrations							
	Order	**Family**	**No. of known species**	**Number of aberrant colour species**	**Albinism**	**Leucism**	**Piebaldism**	**Melanism**	**Hypo-melanism**	**Blue-eyed White Morph**	**Undeter-mined**
1	Proboscidea	Elephantidae (Elephants)	1	1	-	1	-	-	-	-	-
2	Sirenia	Dugongidae (Dugong)	1	-	-	-	-	-	-	-	-
3	Scandentia	Tupaiidae (Tree-shrews)	3	-	-	-	-	-	-	-	-
4	Primates	Lorisidae (Loris)	2	-	-	-	-	-	-	-	-
		Cercopithecidae (Monkeys and Langurs)	20	3	4	1	-	-	7	-	-
		Hylobatidae (Ape)	1	-	-	-	-	-	-	-	-
5	Rodentia	Sciuridae (Squirrels)	27	7	10	4	-	1	1	-	1
		Dipodidae (Birch, mice)	1	-	-	-	-	-	-	-	-
		Platacanthomyidae (Dormouse)	1	-	-	-	-	-	-	-	-
		Spalacidae (Bamboo Rat)	2	-	-	-	-	-	-	-	-
		Cricetidae (Voles)	13	-	-	-	-	-	-	-	-
		Muridae (Gerbills, rats, mouse)	56	6	2	2	5	2	-	-	-
		Hystricidae (Porcupines)	3	2	-	-	-	-	-	-	2
6	Lagomorpha	Ochotonidae (Picas)	7	-	-	-	-	-	-	-	-
		Leporidae (Rabbits, hares)	4	-	-	-	-	-	-	-	-
7	Erinaceomorpha	Erinaceidae (Hedgehogs)	4	1	1	-	-	-	-	-	-
8	Soricomorpha	Soricidae (Shrews)	29	1	1	-	-	-	-	-	-
		Talpidae (Moles)	2	-	-	-	-	-	-	-	-
9	Chiroptera	Pteropodidae (Fruit bats)	14	1	-	-	-	-	-	-	1
		Rhinolophidae (Horse-shoe bats)	17	-	-	-	-	-	-	-	-
		Hipposideridae (Leaf-nosed bats)	13	3	2	-	-	-	-	-	2
		Megadermatidae (Vampire bats)	2	-	-	-	-	-	-	-	-
		Rhinopomatidae (Mouse-tailed bats)	3	2	2	1	1	-	-	-	-
		Emballonuridae (Tomb bats)	6	1	1	-	-	-	-	-	-
		Molossidae (Free-tailed bats)	4	-	-	-	-	-	-	-	-
		Vespertilionidae (Evening bats)	58	-	-	-	-	-	-	-	-
10	Pholidota	Manidae (Pangolins)	2	-	-	-	-	-	-	-	-
11	Carnivora	Felidae (Big cats)	16	6	2	9	2	46	9	3	6
		Viverridae (Civets)	9	2	3	-	2	-	-	-	
		Herpestidae (Mongoose)	6	2	1	-		-	-	-	1
		Hyaenidae (Hyenas)	1	-	-	-		-	-	-	
		Canidae (Fox, wolves, dogs)	7	3	-	2		5	1	-	

					Number of instances in various colour aberrations						
	Order	**Family**	**No. of known species**	**Number of aberrant colour species**	**Albinism**	**Leucism**	**Piebaldism**	**Melanism**	**Hypo-melanism**	**Blue-eyed White Morph**	**Undeter-mined**
		Ursidae (Bears)	4	2	2	-		-	10	-	
		Mustelidae (Otters, weasels)	15	-	-	-		-	-	-	
		Ailuridae (Red panda)	1	-	-	-		-	-	-	
12	Perissodactyla	Equidae (Horses)	2	-	-	-		-	-	-	
		Rhinocerotidae (Rhinoceros)	2	-	-	-		-	-	-	
13	Artiodactyla	Suidae (Wild boars)	2	1	2	-		-	-	-	
		Tragulidae (Mouse deers)	1	-	-	-		-	-	-	
		Moschidae (Musk deers)	4	-	-	-		-	-	-	
		Cervidae (other deers)	8	4	16	5	1	5	2	-	7
		Bovidae (Gaurs, antelopes, goats, yak)	21	8	3	9	2	2	14	-	12
14	Cetacea	Balaenopteridae (Baleen whales)	6	-	-	-		-	-	-	
		Delphinidae (Dolphins and other whales)	13	-	-	-		-	-	-	
		Phocoenidae (Porpoises)	1	-	-	-		-	-	-	
		Physeteridae (Sperm whales)	3	-	-	-		-	-	-	
		Platanistidae (River dolphins)	1	-	-	-		-	-	-	
		Ziphiidae (Beaked whales)	2	-	-	-		-	-	-	
Total	**14**	**48**	**421**	**56**	**52**	**34**	**13**	**61**	**44**	**3**	**32**

The list interestingly shows a total of 421 species against the list of 420 species in Pradhan & Talmale (2012). This is due to the record of colour aberration in Indian Cheetah which has since become extinct.

CONCLUSIONS

The present study indicates colour aberrations in 55 mammalian species belonging to eight orders and 19 families. No report of any type of colour aberration was reported so far from the six different mammalian orders, namely, Sirenia, Scandentia, Logomorpha, Pholiodota, Perisodactyla, and Cetacea from India (Table 3). Elsewhere in the world, there were recorded instances of colour aberration in marine mammals, such as in 25 Neotropical cetacean species (Abreu et al. 2013). The gaps in the knowledge in species belonging to many orders and families in India need attention from researchers, naturalists, and field workers to gather more evidence.

Singh (2014) pointed out that in the past the source of information and dissemination of data pertaining to wildlife and natural history was not as broad-based as it is today. The recent adoption of camera traps for surveys and the easy availability of photographic equipment offers a ray of hope to fill the gaps in knowledge. We highly recommend surveys with camera traps and visual observations in more and more areas to get a better understanding of colour aberrations in the missing species.

It is noticeable that the most commonly observed colour aberration as noted by the original authors is that of albinism. Partly this might be due to the tendency amongst naturalists to name most mutations resulting in white animals as albinos. This, however, is not always true as there are many other types of colour aberration that can result in a white or pale coat. Albinos can be distinguished by their red or pink eye colour along with pinkish snout, pinna, and limbs. Hence, there is a need

Table 4. State-wise records with known instances of various colour aberrations in mammals of India.

States	Number of records of each aberration							
	Albinism	Leucism	Piebaldism	Melanism	Hypo-melanism	Blue-eyed white morph	Undeter-mined	Total
Andaman & Nicobar	2							2
Assam	3	2		5			2	12
Arunachal Pradesh								0
Bihar		3	1	3	4	1		12
Chandigarh	1							1
Chattisgarh				1				1
Goa	2	1		1				4
Gujarat	4	6		1	1		2	14
Haryana								0
Himachal Pradesh		1					1	2
Jammu & Kashmir				1				1
Jharkhand	1							1
Karnataka	4	1	1	8			2	16
Kerala	1	4		6	5			16
Madhya Pradesh	5	4	1	4	8	1	2	25
Maharashtra	8	2	4	9	1		2	26
Manipur							2	2
Meghalaya			1					1
Mizoram								0
Nagaland					1			1
New Delhi	1			1				2
Odisha	2			4	1		2	9
Rajasthan	11	5	2				3	21
Sikkim				2	3			5
Tamil Nadu		3	1	3	9		8	24
Telangana					1			1
Tripura								0
Uttar Pradesh	1	1			1			3
Uttarakhand	4			4			1	9
West Bengal	1		1	7	4	1		14
Unknown	1	1	1	1	5		5	14
Total	**52**	**34**	**13**	**61**	**44**	**3**	**32**	**239**

for greater awareness of types of colour aberration in the naturalists' community to correctly name the aberration.

We encourage researchers and the nature loving community to either publish their observations in scientific journals and to upload photographic evidence on websites such as www.indianaturewatch.com or apps like iNaturalist. Observation and images of eye colour along with the rest of the body are very useful to determine the precise category of colour aberration. Whenever images are not available, a detailed description including eye colour, pattern, and amount of discolouration is necessary for the proper identification of the type of colour aberration in the species.

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सारांश

भारतासह जगभरात सस्तन प्राण्यांमध्ये वेगवेगळ्या रंगविकृती (जसे अल्बिनीझम्, ल्युसिझम्, पायबाल्डीझम्, मेलॅनिझम्, हायपोमेलॅनिझम् आणि निलनेत्रिय श्र्वेतरुप) आढळतात. या परिक्षणात भारतीय सस्तन प्राण्यांमध्ये आढळलेल्या अश्या एकूण २३९ नोंदी, त्यांचे स्थान दर्शविणार्या नकाशांसह, सारणीबद्ध केलेल्या आहेत. या नोंदी १८८६ ते जुलै २०१७ पर्यंतच्या काळात विविध वैज्ञानिक साहित्ये आणि नियतकालिकांमधून प्रकाशित झालेल्या, तसेच विविध वेबसाइट्सवर अपलोड केलेल्या प्रतिमांमधून एकत्रित केलेल्या आहेत. या नोंदींचे त्यांचे जैविक गण आणि कुळांनुसार परिक्षण व विश्लेषण केलेले आहे. त्यात मिळालेल्या माहितीनुसार योग्य रंगविकृतीची ओळख करण्याचा प्रयत्न केला गेला आहे. भारतात आढळणार्या सस्तनप्राण्यांच्या एकूण ४२१ जातींपैकी ५६ मध्ये, म्हणजेच १३.३% जातींमध्ये विविध प्रकारच्या रंगविकृती आढळून आल्या. या जाती आठ गण आणि १९ कूळांमधल्या आहेत. यापैकी २१.८% अल्बिनो, १४.२% ल्युसिस्टिक, ५.४% पायबाल्ड, २५.५% मेलॅनिस्टिक, १८.४% हायपोमेलॅनिस्टिक आणि १.३% निलनेत्रिय श्र्वेतरुपी आहे. उर्वरित १३.४% रंगविकृतींबद्दल माहितीअभावी निश्चित ठरविता आल्या नाही. या अभ्यासातील काही ठळक गोष्टी अश्या आहेत – १) जगभरातील इतरत्र झालेल्या अभ्यासांशी विसंगत असे वेस्परटीलिओनिडे या सस्तन प्राण्यांच्या सर्वात मोठ्या कुळात रंगविकृतींची एकही नोंद न दिसून येणे २) गुजरातमध्ये चितळ आणि काळवीटांमध्ये अल्बिनिझमचा सातत्याने आढळ, ३) भारतातील मेलॅनिस्टिक बिबळ्यांची मोठी संख्या तसेच अलिकडे गेल्या काही वर्षांपासून सिक्किममध्ये मेलॅनिस्टिक आशियाई सुवर्ण मांजरीच्या नोंदी, ४) पश्चिम घाटांच्या दक्षिण भागातील गव्यांमध्ये, मागील काही वर्षांचा अपवाद वगळता, हायपोमेलॅनिझमचा नियमित आढळ. एकूणच, सस्तन प्राण्यांमधील रंगविकृतींचा सखोल अभ्यास होण्याची गरज अधोरेखीत केलेली आहे.

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Nesting trees of the Red Giant Gliding Squirrel *Petaurista petaurista* (Mammalia: Rodentia: Sciuridae) in a tropical forest of Namdapha National Park, India

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Abstract: The present study investigated the nesting habits of the Red Giant Gliding Squirrel in the tropical forest of Namdapha National Park, India within the time period of 2012–2013. Gliding squirrel nest trees were located by searching for them with using spotlighting during evenings and early mornings. For each den site we recorded data on nesting tree species, total height of tree, height of the nest on tree, tree diameter at breast height (DBH), and canopy connectivity of the nesting tree. We observed *P. petaurista* using cavity nests (n=27) in eight tree species. The majority of nest trees observed were in *Altingia excelsa* (40.7%) and *Terminalia myriocarpa* (22.2%). Trees with less canopy connectivity were preferred for nesting where 59.3% of nest trees had <25% canopy connectivity. *Petaurista petaurista* nested in trees with an average of 31.1±0.86m (Mean ± SE) height and the nests were located at a mean height of 17.8±0.89m (SE) (min & max: 9.3m & 35.2m). Mean DBH of nesting trees was 70.6±0.98cm (SE) (min & max: 38.2cm & 168.8cm). This data helps in filling the gaps on the denning ecology of the species and may be useful for the management and conservation purpose of forest trees.

Keywords: Arboreal nests, Arunachal Pradesh, giant gliding squirrels, canopy connectivity, northeastern India, secondary cavity nesters.

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Author contribution: MCK did all the field work and wrote the manuscript. AK helped in planning the study and was responsible for planning the course of manuscript. OPT helped in planning the survey for collecting and analyzing the data on vegetation.

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IDEA WILD

Government of India
Department of Science & Technology

INTRODUCTION

Understanding the ecology of a species is crucial for its conservation and management. Although mammals are among the most studied taxon groups, the ecology of nocturnal arboreal mammalian ecology remains understudied (Bonnet et al. 2002; Clark & May 2002; Jayasekara et al. 2007). Due to knowledge gaps, nocturnal arboreal mammals, such as gliding squirrels, are underrepresented in conservation action plans (see Koprowski & Nandini 2008; Datta & Nandini 2014).

Nesting ecology of gliding squirrels is an important aspect of their biology and is pertinent to their conservation and management. Gliding squirrels use nests for diurnal refuge, shelter from predators and adverse weather conditions, reproduction, and hoarding sites (Cowan 1936; Weigl & Osgood 1974; Weigl 1978; Lee et al. 1986; Bendel & Gates 1987; Shafique et al. 2009). Three types of nests are used by gliding squirrels — tree-cavities, external leaf nests and subterranean nests (Carey et al. 1997; Hackett & Pagel 2003; Holloway & Malcolm 2007). The availability of large, dying, and dead trees has been found to influence nesting strategies among gliding squirrels (Carey et al. 1997; Menzel et al. 2004). Subterranean nests are the least common ones that are observed under the tree roots, downed logs and under rocks (Gerrow 1996; Hackett & Pagels 2003; Diggins et al. 2015). In areas with high snag densities, cavity nests tend to be most prevalent, and in low snag areas with timber harvesting and low cavity availability high external nest use is observed (Carey et al. 1997). At times, drey's are even observed where the squirrels build nests in the tree branches (Hanski et al. 2000). Of the various nesting types discussed above, cavity-nesting has evolved as an adaptation to avoid predation (Martin 1998) and such nesting is considered important for gliding mammals like gliding squirrels (e.g., Taulman 1999; Holloway & Malcolm 2007) and gliding marsupials (e.g., Traill & Lill 1997; Lindenmayer 2002).

The objective of our study was to determine nesting tree characteristics of the Red Giant Gliding Squirrel in tropical forests of Namdapha National Park of Arunachal Pradesh, India (Image 1).

Image 1. Red Giant Gliding Squirrel in Namdapha National Park, Arunachal Pradesh.

MATERIAL AND METHODS

Study Site

The study was carried out at Namdapha National Park (NNP; 27.391–27.661 ^{0}N & 96.250–96.975 ^{0}E; area 1,985km²) which lies in the eastern Himalayan region of Arunachal Pradesh, India (Fig. 1). The park contains some of the northernmost tropical rainforests of the world (Proctor et al. 1998) and the temperature in the park varies along with altitude ranging between 4–35 ^{0}C at altitudes below 2,000m and at higher elevations, the temperature often drops below the freezing point in winters (Ray et al. 2015). Monthly precipitation ranges from a minimum of 1,400mm and maximum of 2,500mm, 75% of which falls between April and October (Kumar et al. 2009). Details on park vegetation are reported by Ghosh (1987), Nath et al. (2005), and Ray et al. (2015). Our study was carried out in Deban (27.483^{0}N; & 96.383^{0}E), Gibbons Land (27.500^{0}N & 96.316^{0}E) and Hornbill Camp (27.533^{0}N & 96.433^{0}E) (Murali et al. 2014) areas within the park and the elevation range of these three study sites range between 200m and 550m. The study sites are dominated by tall trees ranging from 15m to 45m including common species such as *Duabanga grandiflora*, *Neolamarckia cadamba*, *Biscofia javanica*, *Cinnamomum* sp., *Shorea assamica*, *Castanopsis* sp., *Ficus* sp., *Syzygium fruticosum*, *Spondius axillaris* and *Toona ciliata*. Our study sites were approximately 5–10 km apart from each other. All three sites were selected based on the frequent sighting of Red Giant Gliding Squirrels and site feasibility.

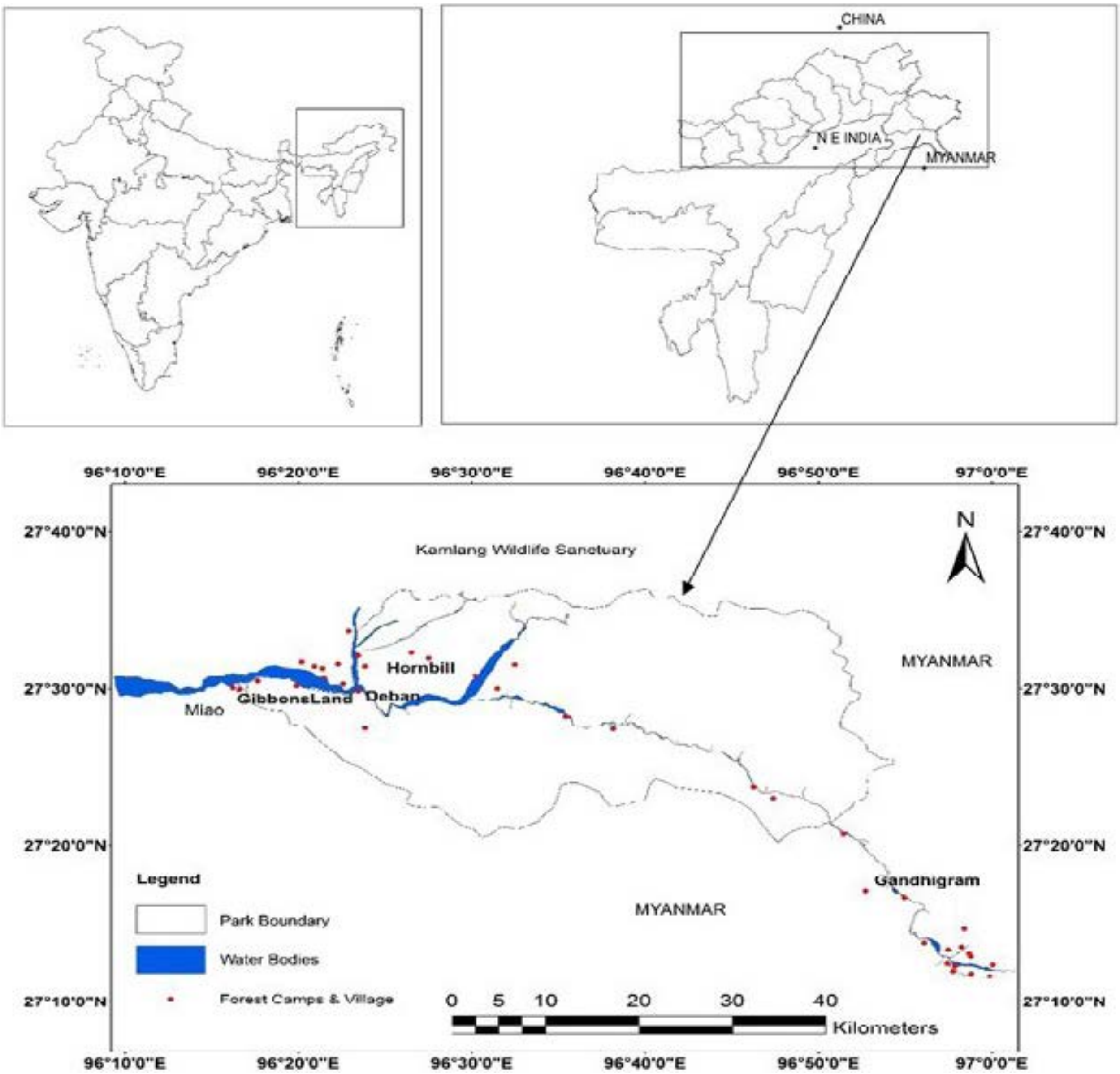

Figure 1. The study area (Namdapha National Park) and study locations (Kuladip Sarma and Parimal C. Ray).

Investigation of nesting cavities

The data on the squirrel nests was collected from October 2012 to September 2013. A minimum of 4–5 days were spent in the field per month during the study period to locate the nests. The nests were located by searching for gliding squirrels with headlamps (Energizer HDL33A2E (Energizer, USA)), during the evenings (17.00h) and early mornings (04.00h) when gliding squirrels usually leave and return to their nests (Shafique et al. 2009). Only those trails, however, were monitored which were marked for estimating encounter rates of the species. Also, opportunistic sightings of the nests were also included in the data whenever a nest was sighted. Upon locating the nesting site, the following nesting characteristics were recorded: tree species, total height of the nesting tree (m), height of the nest on the tree (m), diameter at breast height (DBH) (cm) of the tree, and canopy connectivity of the nesting tree. The height of the nest was measured using laser distance measurer (Bosch GLR225; accuracy ±1m (Robert Bosch GmbH, Germany). We followed Herlekar (2010) to determine canopy connectivity of the nesting tree, where connectivity was calculated based on the canopy shared by neighbouring trees. If the nesting tree was covered by canopy on four sides, we considered the canopy connectivity was 100%, whereas if nesting trees canopy had canopy connectivity on three, two, one, or no sides, connectivity was considered 75%, 50%, 25%, or 0%, respectively (Herlekar 2010). Additionally, to compare selected trees to nearby trees, we measured DBH (cm), tree height, and distance from nesting tree (m) of the four nearest trees to each individual nest tree. The nearest trees were identified based on the four imaginary quartiles which lie around the nesting tree. All the distances and tree heights were measured using a Nikon Rangefinder (Nikon 6x21 Forestry Pro, Nikon Corporation, Tokyo, Japan).

The lengths of census trails ranged between 0.5km and 2km. All the trails surveyed were pre-existing and no fresh trails were cut in order to minimise the disturbance in the area. Data on vegetation was collected along these trails using point centred-quarter method (Cottam & Curtis 1956). Absolute density and relative density of the trees were calculated following Mitchell (2010) where the absolute density of a species was estimated as the proportion of quarters where the species was found.

RESULTS

We observed Red Giant Gliding Squirrels using a total of 27 nests during the study and also found that the Red Giant Gliding Squirrel used eight tree species for nesting (Image 2): *Altingia excelsa* (n = 11), *Terminalia myriocarpa* (n=6), *Castanopsis indica* (n = 3), *Shorea assamica* (n=2), *Syzygium fruticosum* (n=2), *Cinnamomum bejolghota* (n=1), *Cinnamomum glaucescens* (n=1), and *Artocarpus chaplasha* (n=1). The nest trees exhibit low canopy connectivity, where most trees had <25% canopy connectivity (59.3% of nest trees), followed by 25.9% of nests with 50% canopy connectivity, and 14.8% of nests with connectivity >75%. The mean measurements of the nesting tree species are presented in Table 1.

Of the neighbouring trees (n=108) observed adjacent to nesting trees, ~93% (100 trees belonged to 25 species) were living trees and 7% (8 trees) were dead snags. And among the 25 species, nine species (n=61) were observed as feeding trees (Table 2). Of the 27 identified nesting trees, 24 had canopy connectivity with feeding trees. 12.5% of nesting trees were surrounded by four

Image 2. Nesting tree with juvenile of Red Giant Gliding Squirrel in Namdapha National Park, Arunachal Pradesh.

Table 1. Characteristics of nesting trees used by Red Giant Flying Squirrels in northern India during 2012-2013 (Data are mean±SE).

	Tree species	Family	Absolute density (individuals ha^{-1})	Mean basal Area (m^2 ha^{-1})	Mean height of the nesting tree (m)	Mean height of the nest (m)	Mean DBH of the nesting tree (cm)	Mean DBH of the nearest tree (cm)	Mean distance to the nearest tree (m)
1.	*Altingia excelsa*	Altingiaceae	17.4	0.22	31.1±1.3	16.5±1.02	79.2±11.64	40.5±1.74	12.6±0.76
2.	*Terminalia myriocarpa*	Combretaceae	10.2	0.33	31.5±0.95	17.8±0.95	70.8±5.45	40.14±2.19	12.08±0.9
3.	*Castanopsis indica*	Fagaceae	4.1	0.12	29.1±1.31	17.5±0.93	59.96±7.79	41±2.19	16.9±2.28
4.	*Shorea assamica*	Dipterocarpaceae	4.4	0.14	33.7±3.6	15.5±0.65	72.45±21.45	35.03±2.3	12.75±1.29
5.	*Syzygium fruticosum*	Myrtaceae	10.0	0.13	25.6±5.8	20.9±5.6	53.3±15.5	40.8±4.79	12.12±1.92
6.	*Cinnamomum bejolghota*	Lauraceae	0.8	0.20	28.9±0.0	17±0.0	69.4±0.0	37.82±1.88	15.5±3.22
7.	*Cinnamomum glaucescens*	Lauraceae	2.5	0.13	30.2±0.0	14.3±0.0	57.3±0.0	35.05±3.2	8.75±0.85
8.	*Artocarpus chaplasha*	Moraceae	1.0	0.08	41.3±0.0	35.2±0.0	52.5±0.0	37.42±3.7	10.5±0.95

Table 2. Tree species observed nearby *P. petaurista* nesting trees and their absolute and relative density and mean basal area in northern India during 2012–2013.

Tree species	Absolute density (individuals ha^{-1})	Relative density (individuals ha^{-1})	Mean basal area (m^2 ha^{-1})
Ailanthus grandis	1.1	0.8	0.22
*Altingia excelsa**	17.4	13.2	0.2
*Artocarpus chaplasha**	1.0	0.7	0.08
Biscofia javanica	2.8	2.2	0.23
*Castanopsis indica**	4.1	3.1	1.2
*Chukrasia tubularis**	2.8	2.2	0.2
Cinnamomum glaucescens	2.5	1.9	0.1
*Cinnamomum bejolghota**	0.8	0.6	0.2
Dipterocarpus macrocarpus	1.8	1.4	0.2
*Duabanga grandiflora**	2.6	1.9	0.2
Dysoxylum gobara	5.0	3.8	0.09
Elaeocarpus floribundus	0.7	0.6	0.06
Gmelina arborea	3.9	2.9	0.1
Gynocardia odorata	0.6	0.5	0.05
Macaranga denticulata	3.6	2.7	0.04
Magnolia hodgsonii	5.6	4.3	0.08
Mangifera sp.[#]	-	-	-
Mesua ferrea	1.9	1.4	0.03
*Neolamarckia cadamba**	1.2	0.9	0.08
Pterospermum canescens	1.3	0.9	0.2
Shorea assamica	4.4	3.3	0.15
Spondias axillaris	2.4	1.8	0.14
*Syzygium fruticosum**	10.0	7.6	0.13
*Terminalia myriocarpa**	10.2	7.7	0.33
Toona ciliata	3.0	2.3	0.07

* Feeding trees (as per Krishna et al. 2015).
[#] The data was not enumerated as the species did not lie in the vegetation plots.

feeding trees, 33.3% were connected with three feeding trees, 45.8% were connected with two feeding trees, and 8.3% were connected with a single feeding tree.

DISCUSSION

Studying the life history traits and ecology of gliding squirrels is difficult due to their nocturnal habits and secretive nature. Our study is the only document presenting the nesting preferences of the Red Giant Gliding Squirrel in India till date. During the study period we observed Red Giant Gliding Squirrels nesting only in the cavities. This may be due to availability of tree cavities for nesting at our study site. Firstly, cavities may provide better protection than drey from predators, such as arboreal civets (Krishna et al. 2015). Secondly, the study area receives heavy rainfall during monsoon and thus cavity nests may offer more protection from inclement weather than drey nests. The Japanese Giant Gliding Squirrel *Petaurista leucogenys* drey's are observed in areas where there was scarcity of tree hollows (Haneda 1955; Tachibana 1957). Also, it was noted that the species preferred large trees with higher DBH for nesting. Similar observations were reported earlier in many other studies (see table 3). In general, gliding squirrels are reported to need tall mature forests for nesting as they are cavity nesters (Ransome et al. 1997) and are critically dependent on mature forests for food, and movement (Verbeylen et al. 2009). The gliding squirrel nests usually were several meters off the ground and located much lower from the point where branches originated (nearly 5–7 m), which may enable unobstructed access to the nest tree. Also, trees with less canopy connectivity were occupied more when compared to trees with more canopy connectivity which might be a reason to avoid predation pressure as discussed above. Gliding squirrels are predated by an array of mammals and birds (Taulman et al. 1998; Fan & Jiang 2009; Sun et al. 2009) and variables such as cavity height, entrance size, and condition of cavity trees are especially important factors for predator avoidance. To decrease predation risks, gliding squirrels select high

Table 3. Comparison of nesting characters of *Petaurista* species globally.

	Species	Results	References
DBH of the nesting tree (cm)			
1.	*P. petaurista albiventer*	77.22±18.67 SD	Shafique et al. 2009
2.	*P. alborufus*	60–80	Lee et al. 1986
3.	*P. philippensis*	25–52	Lee et al. 1986
4	*P. philippensis*	301.6±69.88 SD	Koli et al. 2013
5.	*P. leucogenys*	20–140	Ando & Shiraishi 1983
6.	*P. petaurista*	70.6±0.98 SE	Present study
Height of the nest (m)			
1.	*P. philippensis*	10–12	Fan & Jiang 2009
2.	*P. philippensis*	10.07±3.22	Koli et al. 2013
3.	*P. petaurista*	17.8±0.89	Present study
Distance to the nearest tree (m)			
1.	*P. philippensis*	11.07±6.12	Koli et al. 2013
2.	*P. petaurista*	12.86±0.49	Present study

cavities with small entrances in live trees (Wesolowski 2002; Ruczynski & Bogdanowicz 2005; Mitrus & Socko 2008; Kosinski et al. 2011).

In the present study, it was observed that the Red Giant Gliding Squirrel typically had one or more feeding trees located adjacent to a nest tree. During our study, it was observed that the individuals groomed initially after emerging from the nest and then glided to the nearest food tree for feeding unless the nesting tree is not a feeding tree. In a study conducted on Grizzled Giant Squirrel *Ratufa macroura* in southern India, gliding squirrels preferred nesting in areas with higher food tree availability (Herlekar 2010). In the Sierra Nevada Mountains, USA, Northern Gliding Squirrels *Glaucomys sabrinus* were reported to select specific tree species for nesting due to greater availability of hypogeal fungi food items associated with that tree species (Meyer et al. 2005). Red Giant Gliding Squirrel preference of nesting in *Altingia excelsa* and *Terminalia myriocarpa* in the present study could be due to high abundance of the listed two tree species and larger height of these tree species in the study area. Additionally, the branching of *Altingia excelsa* occurs higher on the trunk versus other species, providing tall naked trunks which provide easier access to nest cavities.

Though we compared the present study to various studies with regard to nesting habits of the giant gliding squirrels, understanding forest composition and structure, habitat quality, and anthropogenic disturbance, frequency of use of nests by species, duration of use need to be studied for better understanding of the nesting preferences. Also, from the present data, we cannot conclude the exact nesting preferences of the study species statistically due to smaller sample size. Habitat management, however, aimed at conserving cavity trees may be needed to conserve gliding squirrels, and those cavities and cavity trees that they selectively use should be preferentially conserved (Suzuki et al. 2013). Although our study indicates that large old trees of *Altingia excelsa* and *Terminalia myriocarpa* were typically selected, our small sample size has limited inference for making recommendations to forest management, however, it has to be noted that the species prefers old trees with natural cavities for nesting. On the whole, stress on additional studies to examine long-term nest use by the species and to compare characteristics between nest trees and a random sample of forest trees is highly recommended to better understand the nesting preference of the species.

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Insights into the diet and feeding behaviour of Red-capped Lark *Calandrella cinerea* (Aves: Passeriformes: Alaudidae)

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Abstract: Anthropogenic activities have continued to threaten critical habitats of many tropical birds. Few studies, however, have established the habitat requirements, diet and foraging strategies of the threatened species to guide conservation efforts. The Red-capped Lark *Calandrella cinerea*, which inhabits tropical grasslands in Africa is highly threatened by habitat loss and anthropogenic activities such as burning for pasture regeneration and overgrazing by livestock. Many aspects of the feeding behaviour of this threatened tropical lark are still unknown. We studied the diet and feeding behaviour of the adult Red-capped Lark in its open grassland habitat at Kedong, Naivasha, Kenya from 04 March 2016 to 12 August 2016. Findings revealed that birds predominantly consumed animal nutrients that included insect larvae/caterpillars, grasshoppers, moths/butterflies, ants, and beetles. This was supplemented with plant nutrients (grass seeds) from two grass species, *Eragrostis tenuifolia* and *Harpachne schimperi*. Picking and gulping were the most employed food capture and handling techniques respectively. In relation to foraging substrates, grass substrate was most selected for food capture as compared to large mammal dung and soil mounds. Given that tropical grasslands are becoming increasingly threatened biomes, the findings are critical in guiding the management of grassland habitats of birds to ensure their protection from negative impacts as well as deepen understanding on how they adapt to environmental changes.

Keywords: Africa, Anthropogenic activities, foraging strategies, habitat requirements, habitat loss, threatened birds open grassland habitat.

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Author Contribution: MM conducted the fieldwork under the instructions and supervision of RC, NG and PN. RC, NG and PN guided MM in data exploration, analysis and drafting of this manuscript. All the authors reviewed the final manuscript and approved its submission.

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INTRODUCTION

Loss of habitat has become one of the greatest threats to the survival of many bird species all over the world (Thivyanathan 2016). As negative impacts of anthropogenic activities continue to intensify in and around tropical grasslands, bird species that depend on such habitats face serious threats of local extinction. There is, therefore, a need to understand how birds adapt to their habitats as well as inter-specific interactions that they have with other conspecific species (Davis 1977; Benton et al. 2002; Clancy 2011). This knowledge is essential for effective species protection and habitat management (Mansor & MohdSah 2012). In Kenya, the Red-capped Lark (Image 1) inhabits dry/warm tropical and wet/cool montane grasslands (Ndithia et al. 2017). Despite the increasing threat to its grassland habitats, few studies have been conducted on its food resource in relation to diet and feeding behaviour. This study therefore assessed the feeding behaviour of the Red-capped Lark in Kedong Valley, an extensive tropical grassland area in Naivasha, Kenya. The objectives of the study were to determine the dietary composition and feeding behaviour of the resident population of Red-capped Lark. We hypothesized that diet and feeding behaviour would not be influenced by seasonality and insect prey availability.

Image 1. Red-capped Lark *Calandrella cinerea.*

MATERIALS AND METHODS

This study was undertaken at Kedong ranch (0.893^{0}S & 36.398^{0}E, 2,077m) in Naivasha, located in Kenya's Central Rift Valley (Fig. 1). It lies between two conservation areas (Hell's Gate and Longonot national parks) hence, it is of high conservation priority (Bennun & Njoroge 2001). The study area supports a wide range of wildlife species, including a resident population of Red-capped Lark. It is exposed to intensive grazing by livestock and wildlife. The tropical climate of the area is characterized by a bimodal rainfall pattern with annual average rainfall of 600–1100 mm and an annual average temperature of 25.0^{0}C. The natural vegetation is dominated by tall perennial grasses, particularly *Pennisetum mezianum*, *Themeda triandra*, *Eragrostis tenuifolia, Chloris virgata, Cynodon nlemfuensis (var.nlemfuensis)*, and *Harpachne schimperi*. The most common forbs growing amongst the grasses are *Felicia muricata* and *Indigofera bogdanii* while common tree species include *Acacia xanthopholea*, *Acocanthera schimperi* and *Euphorbia candelabrum*. Fieldwork was conducted from 04 March to 12 August 2016, with breeding period between (March and May) and (June and July) while non-breeding between June and August. Data on feeding behaviour were obtained through focal animal sampling (Martin & Bateson 1988; Nhlane 1992; Akinpelu & Oyedipe 2004). Focal individuals were selected randomly and observations on feeding made from a distance of about 50m using a telescope (Akinpelu & Oyedipe 2004). The observations were conducted in the morning (0700—1100 hr) and late in the afternoon (1600—1800 hr) when birds were most actively feeding (Felicity et al. 2014). Each focal individual was observed for 15 minutes and if stopped foraging or went out of view, another adult bird was selected to complete the observation period (De Melo & Guiherme 2016). Timed data on feeding was recorded (Block 1991) including food items consumed by birds, food capture technique, food handling technique and foraging substrate selected for food capture. A total of 136 hours of observation on non-consecutive days were completed on 176 birds (82 birds during breeding and 94 birds during non-breeding periods). In order to control variability of measurements, data collected were tested for normality using the R-QQ plot for normality and, where appropriate, Shapiro-Wilk Test. Statistical tests were performed using R-program version 3.2.1 and PAST software. To establish the relationship between food availability and utilization by the Red-capped Larks, mean weekly consumption rates were correlated with mean weekly captures of various types of insect prey. Differences in food capture and handling techniques were evaluated using two-sample t-test. The mean values of test variables were reported as mean ± SE. In all the statistical tests conducted, significance of the test was checked at $\alpha < 0.05$.

Figure 1. A composite map showing location of the study area in Kenya. (Source: Google Maps)

RESULTS

Diet and utilization of food resource

The study revealed that diet of the Red-capped Lark comprised both insect food and plant diet (grass seeds), with insect diet being predominant. During breeding period, 63.2% (n = 221 observations) of diet was insect food and 36.8% (n = 131) plant food (grass seeds). Furthermore, during the non-breeding period, 81.5% (n = 421) of diet was insect food and 18.5% (n = 95) grass seeds. Insect diet comprised of insects in the orders Coleoptera, Orthoptera, Lepidoptera, and Hymenoptera. Out of six grass species identified in the open grassland habitat area of the Red-capped Lark (*Eragrostis tenuifolia, Chloris virgata, Cynodon nlemfuensis* (*var. nlemfuensis*), *Themeda triandra, Harpachne schimperi* and *Pennisetum mezianum*) the larks predominantly consumed seeds from only two grass species; *Eragrostis tenuifolia* and *Harpachne schimperi.* There was, however, a clear seasonal pattern with birds consuming more grass seeds (36.8% of diet) during the breeding period than during non-breeding period (18.5% of diet). The prey preferences by birds were calculated by converting observations of positively identified items into the proportion of total feeding observations made. During the breeding period, 221 feeding observations involving consumption of insect prey were completed. Insects in the order Orthoptera (21.9% of diet; n = 78), Lepidoptera (20% of diet; n = 45) and Coleoptera (12% of diet; n = 27) comprised the largest proportion of the insect diet. Insects in the order Hymenoptera (7% of diet; n=16) accounted for the lowest proportion (Fig. 2). During non-breeding period, 421 observations on consumed insect food items were completed. The most frequently consumed insects were those in the orders Orthoptera (28.4% of diet; n = 119) Lepidoptera (18.02%; n = 76) Hymenoptera (17.6%; n = 74) and Coleoptera (17.4%; n = 73) (Fig. 2).

The availability and abundance of different food items influenced consumption rate and mode of food sourcing. When availability of insect prey items in the grassland was correlated with mean weekly consumption rates of prey items by the sampled adult birds, Pearson's correlation coefficients for individual insect groups showed positive relationships between availability and utilization of insect prey items. There was a significant

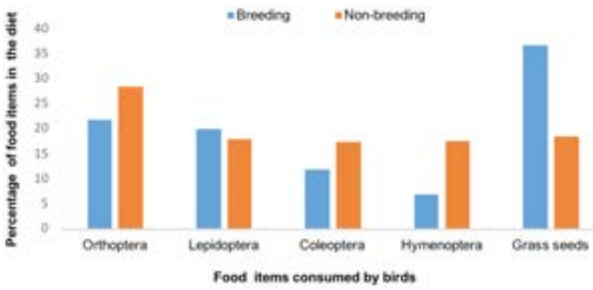

Figure 2. Dietary preferences of Red-capped Lark during breeding and non-breeding periods.

Table 1. The Red-capped Larks selection of foraging substrates (grass, dung and soil mounds) for food capture.

Breeding period			Non-breeding period		
Type of substrate	n	% in frequency	Type of substrate	n	% in frequency
Grass	337	94.6%	Grass	420	81.3%
Dung	12	3.3%	Dung	56	10.8%
Soil mounds	7	1.9%	Soil mounds	40	7.7%
Total	**356**	**100%**		**516**	**100%**

positive correlation between insect prey availability and mean consumption rate for insects in the order Lepidoptera (r^2 = 0.57, p<0.05). There was, however, non-significant positive correlation for Coleoptera (r^2 = 0.19, p<0.05), Orthoptera (r^2 = 0.01, p<0.05) and Hymenoptera (r^2 = 0.09, p<0.05).

Food capture and handling techniques

The Red-capped Lark employed active foraging while searching for food on the ground. The two food capture techniques employed by birds were picking (birds picking prey while walking) and run-picking (picking of food that was preceded by a short sprint). Picking was the most common food capture technique during both breeding and non-breeding periods. During the breeding period, there was significant difference in mean rates that birds employed picking (5.5±0.3) as compared to run-picking (0.02 ±0.02) (paired t-test; $t_{0.05, 2, 82}$ = 20.94, p<0.05). During the non-breeding period, there was significant difference in rates of picking prey items (5.3±0.2) as compared to the run-picking (0.1 ± 0.02) ($t_{0.05, 2, 94}$ = 23.35, p<0.05). The directly picked food items included grass seeds, butterflies/moths, insect larvae and grasshoppers. The prey items picked on the run included grasshoppers and butterfly/moths. Tearing & gulping and gulping were the two food handling techniques used by birds. While gulping entailed capturing and swallowing food items directly without manipulation other than being held briefly using the bill, tearing & gulping entailed capturing, and cutting of food into smaller pieces followed by swallowing. Gulping was observed to be the most frequent food handling technique employed. During the breeding season, there was significant difference in the mean rates where birds employed gulping (4.71±0.27) as compared to tearing & gulping (0.92±0.14 times) ($t_{0.05, 2, 82}$ = 11.95, p<0.05). Gulping was used to handle food for 88.2% of feeding bouts observed while tearing & gulping accounted for 11.8% of the bouts. For the non-breeding season, there was significant difference in mean rates that birds employed gulping (4.03±0.24) as compared to tearing & gulping (1.58±0.15) ($t_{0.05, 2, 94}$ = 8.31, p<0.05). Gulping was employed for 69.6% of feeding bouts compared to tearing & gulping which accounted for 30.4% of the bouts. The food items consumed by gulping were often grass seeds, insect larvae, grasshoppers and butterflies/moths while those by tearing & gulping were mostly grasshoppers, beetles, butterflies/moths and insect larvae.

Foraging substrates and their selection for food capture

Although Red-capped Larks predominantly foraged in open grass substrate, other foraging substrates included piles of mammal dung and fresh soil mounds. In the grassland habitat of the Red-capped Lark, fresh soil mounds were often small piles of fresh soil around holes dug overnight by mammals from where birds obtained ants and termites. These microhabitats were ephemeral and were critical as foraging substrates. The foraging substrate most preferred by birds during breeding (94.6% of feeding observations) and non-breeding (81.3% of observations) periods was grass substrate followed by the dung substrate (3.3% of observations during breeding and 10.8% of observations during non-breeding), and soil mounds (1.9% of observations during breeding and 7.7% of observations during non-breeding (Table 1).

DISCUSSION

The study confirmed that the Red-capped Lark is omnivorous and relies on animal food (insect prey) and plant diet (grass seeds). Similar to findings of previous studies on diet of the Red-capped Lark (Winterbottom & Wilson 1959; Borrett & Wilson 1971; Hockey et al. 2005; Mwangi et al. 2018), the study confirmed that its animal diet consists of ants (Hymenoptera), Lepidotera (moths, butterflies and their larvae), Coleoptera (beetles) and Orthoptera (grasshoppers). Although birds feed primarily on insects in orders Orthoptera, Coleoptera, Hymenoptera (Okolie et al. 2015; Mwansat & Tushak

2011), they may prefer insect prey belonging to some orders and not others. A study on insect diet of some afro-tropical insectivorous passerines at the Jos wildlife park in Nigeria also revealed that insects in the family Formicidae (order Hymenoptera) were key insect food source for birds (Mwansat & Tushak 2011). Majority of birds rely on insect diet whose nutritional value is considered adequate due to its rich and easily digestible fat and protein (Okolie et al. 2015). In addition, insect food promotes faster growth in birds by providing them with essential elements of growth such as phosphorous, protein, non-chitin carbohydrates, lipids, vitamins and minerals (Klasing 2000). For Red-capped Larks, feeding is a critical activity for its survival hence these factors are likely to play a role in preference of insect diet in larger proportion than the plant diet.

The Red-capped lark complemented insect diet with grass seeds from two grass species; *Eragrostis tenuifolia* and *Harpachne schimperi*. These results are consistent with findings of another study of stomach contents of Red-capped Larks which confirmed presence of grass seeds of *Brachiaria* and *Setaria* spp. in the diet (Borrett & Wilson 1971). Such seeds are often abundant in the herb layer and dry grass on the ground (Nkwabi et al. 2010). Garnett & Crowley (1999) found seeds of annual grasses such as *Schizachyrium* spp. to be a key food source for tropical grassland birds in Australia. The importance of grass seeds as food for grassland birds has also been revealed in the West African Thrush *Turdus pelios* (Akinpelu & Oyedipe 2004). Grass seeds have high-energy content (Ndithia & Perrin 2006), hence grass substrate acts not only as a habitat for insect prey of Red-capped Larks but also as a source of plant diet. Furthermore, the grassland habitat provides the Red-capped Lark with leaves, fiber and grass needed for nest-construction during the breeding period.

The results of this study revealed that compared to plant diet, the largest proportion of the Red-capped Lark's diet comprised of insect diet with the most abundant insects being the most consumed. This has also been reported in diets of other passerine tropical birds such as the Fork-tailed Drongo *Dicrurus adsimilis* in southwestern Nigeria where its diet comprised of 86% insect prey and 14% plant food (Okosodo et al. 2016). In central Brazil, the diet of the White-naped Jay *Cyanocorax cyanopogon* consisted of 59% insect prey, 28% vegetable food and 13% human food waste (Barros et al. 2014). In the same tropical grasslands of central Brazil, the diet of Curl-crested Jays *Cyanocorax cristatellu* was found to comprise 48% insect diet, 40% plant diet, and 12% flower nectar (Amaral & Macedo 2003). The diet of the Plush-crested Jays *Cyanocorax chrysops* which inhabit glades and edges of the Brazilian Atlantic forests was dominated by insect prey (88.9%) with wild plant foods constituting 3.7% while indeterminate material, such as human food waste comprised 7.4% of the bird's diet (Uejima et al. 2012). Given that utilization of insects by birds is probably a reflection of insect abundance (Mwansat & Tushak 2011), this was also likely to have been the case for the Red-capped Lark where the most abundant insect prey was the most consumed.

Birds provide very critical ecosystem services, with one of the most important service being pest reduction (Barros et al. 2014). The findings of this study suggested that the Red-capped Lark provides this ecosystem service given that it feeds on insect pests such as the Black Maize Beetle *Heteronychus arator*, one of the most important coleopteran pests that feeds on cultivated crops. By feeding on harmful insects, the Red-capped Lark likely plays the role of keeping in check harmful insects that reduce productivity of agricultural crops and quality of stored grains. Such services offered by birds have also been confirmed for tropical birds such as the Common Bulbul *Pycnonotus babatus* population in Nigeria and 11 sympatric bird species in Macadamia Orchards in Australia (Crisol-Martinez et al. 2016).

An important factor that most likely influenced preference of the grassland habitat by the Red-capped Lark was availability of grass seeds and insect food. Preference for grassland over other vegetation types has previously been reported for the Red-capped Lark population inhabiting the grasslands of Serengeti in Tanzania (Nkwabi et al. 2010). Apart from open grasslands, the Red-capped Larks have been observed to prefer heavily grazed pastures (Borrett & Wilson 1971). For avian species, habitats vary in relation to availability of food resource hence the link between insect prey availability and feeding behaviour can be attributed to vegetation type in the habitat. As a result, this makes prey availability (Thivyanathan 2016) and prey visibility (Gokula & Vijayan 2007; Asokan & Ali 2010) to influence successful feeding and define the quality of habitats for birds. The foraging behaviour of birds is influenced by the structure of its habitat given that prey visibility defines quality of a habitat for birds (Gokula & Vijayan 2007; Asokan & Ali 2010). The suitability of a habitat for birds, therefore, is defined by key factors of availability, abundance and distribution of food resource. The vegetation type/cover in a given area influences insect abundance and diversity (Wardle & Barker 1997). In addition, the type of food substrate where birds obtain food from influences food intake rate, type of feeding method and ability to increase vigilance to probably reduce predation risk. In birds, prey availability is a key factor that influences successful foraging (Thivyanathan 2016), and suitability of a habitat for birds is, hence, influenced by the key factors of availability, abundance and distribution of food resource. Habitats vary in the relative availability of food resource for avian species making the relationship between insect prey availability and feeding behaviour to be influenced by the vegetation type in the habitat. Since the Red-capped Lark only inhabits the open grassland in the study area and not adjacent woodlands, positive correlation between insect prey types that were available and utilized is likely to have been due to abundance of the prey in the grassland habitat. Food availability (grass seeds and insect food) due to vegetation structure of the open grassland most likely influenced preference of the habitat by the Red-capped Lark (Robinson & Holmes 1984).

Conclusions and Recommendations

The study of the Red-capped Lark provides valuable insights on the diet and feeding behavior of tropical grassland birds. Changes in the composition of the diet seems to be directly influenced by availability and abundance in the foraging environment and by the physiological requirements of the body. The findings bring out the need for long-term studies on feeding behavior of the Red-capped Lark to shed light on how diet changes in quality with season and how it influences reproductive success. For instance, it would be useful to quantitatively determine the relationship between the size and number of insect prey items consumed by parental and non-parental birds. Quantitative evidence pertaining to these questions would help ecologists to develop predictive models concerning adaptations of tropical grasslands birds to dynamics of the habitat. Furthermore, this information would provide a better understanding of ecology of grassland passerine birds hence guide development of effective conservation strategies. With habitats of many avian species especially in the tropics increasingly becoming fragmented and degraded at a rapid rate, findings of such studies would provide a good framework for co-existence between grassland birds, livestock and people in the wildlife-rich eastern African rangelands.

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PLATINUM
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Baseline biodiversity and physiochemical survey in Parvati Kunda and surrounding area in Rasuwa, Nepal

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Abstract: Parvati Kunda, a small, alpine wetland located near the village of Gatlang in Rasuwa, Nepal, is a major source of drinking water for the village, possesses spiritual significance, and is a reservoir of local biodiversity. This study presents the first scientifically conducted biodiversity survey of the wetland. Here, biodiversity data (wetland plants, birds, mammals, aquatic insects), basic water chemistry (nutrients, pH, dissolved oxygen, conductivity), and basic bacterial tests (total coliform, *Escherichia coli*, Giardia, Salmonella, Shigella) for the Parvati Kunda wetland is presented from November 2016 and February and May 2017. Parvati Kunda, two of three alternate village water sources, and several village taps were found to be contaminated with *E. coli* bacteria. Within and around the wetland, 25 species of wetland plants, nine tree species, 10 macroinvertebrate taxa, 37 bird species, and at least six mammal species were documented. *Acorus calamus* was the dominant wetland plant and the rapid proliferation of this species over the past twenty years has been reported by community members. Future studies that further document and monitor wetland biodiversity are necessary. This study provides a valuable baseline for future research in this culturally and ecologically important wetland.

Keywords: *Acorus calamus*, *Escherichia coli*, eutrophication, Himalaya, wetland monitoring.

Nepalese Abstract: सारस पावर्तीकुण्ड एक सानो तर सांस्कृतिक र पारिस्थितिक रुपमा महत्वपूर्ण उच्च पहाडी क्षेत्रमा अवस्थित सिमसार हो । यो कुण्ड रसुवा जिल्लाको स्थित गत्लाङ गाउँको नजिक रहेको छ । यो गत्लाङ गाउँको लागि पीउने पानीको मुख्य स्रोत हो र यसको स्थानीय जैविक विविधतामा महत्वपूर्ण योगदान भएतापनि त्यसको अभिलेख राखिएको पाईएन । त्यसकारण नोभेम्बर २०१६, फेब्रुअरी २०१७ र मे २०१७ मा यस अध्ययनका विज्ञहरुको टोलीद्धारा चरणबद्ध रुपमा गरिएको सर्वेक्षण र स्थानीय मानिसहरुसँगको अन्तरक्रियाबाट आएको जान्कारीको आधारमा गत्लाङ पावर्तीकुण्ड क्षेत्रमा भएका रुख तथा वनस्पति, स्तनधारी, पंक्षी, शुक्ष्म जीवाणुहरु, जलीय जीवहरुको पहिलो बिस्तृत सूचीको बिकास भएको छ। यसका साथै पावर्तीकुण्ड र आसपासमा भएको पानीको भौतिक–रासायनिक गुण, पानीमा भएका पोषक तत्वहरु तथा पिएच, घुलित अकिसजनको मात्रा, विद्युतिय लचकता जस्ता कुराहरुको वर्तमान मापनको अवस्था थाह भएको छ । गत्लाङ गाउँमा उपयोग हुने पानीका तीनवटा बैकल्पिक स्रोतहरु मध्ये २ वटामा र गाउँमा भएका ५ वटा धाराहरुमा इकोली जीवाणुबाट पानी दुषित भएको पाइएको छे । सिमसार क्षेत्रको वरिपरी २५ प्रजातिका जलीय वनस्पतिहरु, ९ प्रजातिका रुखहरु, १० प्रजातिका शुक्ष्मजीवाणुहरु, ३७ प्रजातिका चराहरु र १० प्रजातिका स्तनधारी जनावरहरुको अभिलेख गरिएको छ । बोझो (*Acorus calamus*) प्रजातिको वनस्पति सिमसार क्षेत्रमा सबभन्दा बढी मात्रामा रहेको पाइयो, जुन बिगत २० वर्षदेखि व्यापक रुपमा बृद्धि भइरहेको छ । यस सर्वेक्षणको अभिलेखले भविष्यमा यस सम्बन्धी हुने अध्ययन अनुसन्धानमा तथा परिवर्तनका प्रवृतिहरुको तुलना गर्न र बुझ्न आधारभूत तथ्याङ्कहरु प्रदान गर्नेछ । पार्वतीकुण्ड सिमसार क्षेत्रको पर्यावरणीय परिमाण/वस्तु/सूचकहरुको निरन्तर रुपमा निरीक्षण र लेखाजोखा गरिरहन सुझाव दिइन्छ ।

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Author contribution: JAM organized and conducted field data collection (plants, trees, macroinvertebrates, water chemistry) and wrote the manuscript. MBS organized field logistics, conducted field data collection (trees, birds, mammals), and consulted on the manuscript. SY acted as project supervisor and consulted on the manuscript.

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INTRODUCTION

The Himalaya, often considered the "water towers of Asia", provide water for almost 1.3 billion people living downstream (Xu et al. 2007). Nowhere, however, are the Himalayan water resources as critical as in the mountains themselves. Communities throughout the Himalaya depend on alpine wetlands for drinking water, rely on wetland flora and fauna for food and medicine, and attach spiritual significance to bodies of water (Pandit 1999; Xu et al. 2009). Furthermore, the Himalayan wetlands provide pristine, favourable habitats for flora and fauna in otherwise harsh mountain environments and are therefore important reservoirs of biodiversity (Murray 2009).

The Himalayan wetlands face many threats. Climate change already causes rapid glacial reduction in many areas and the ongoing rise in temperature will likely impact rain patterns, wetland thermal regimes, and habitat for flora and fauna, jeopardizing sensitive wetland ecosystems and threatening critical water sources (Yao et al. 2004; IPCC 2007; Tse-ring et al. 2010; Gerlitz et al. 2015). Another major threat to the Himalayan wetlands is eutrophication. Eutrophication is characterized by excessive plant and algal growth in a body of water, which often results from human activities that produce excessive nitrogen and phosphorus waste, such as raising livestock or applying fertilizer (Carpenter et al. 1998; Schindler 2006; Binzer et al. 2016). Multiple studies in Himalayan wetlands identified eutrophication from human-generated pollution as a major threat to regional wetland ecosystem health (Khan et al. 2004; Romshoo & Rashid 2014).

Parvati 'Kunda' (Nepali: pond; also called 'Chhodingmo'), a small wetland in the Rasuwa District of Nepal, provides drinking water to the nearby village of Gatlang that consists of about 400 households (Merrey et al. 2018; Fig. 1). Parvati Kunda also holds spiritual significance to the people in Gatlang and is a harbour of local biodiversity. A brief, qualitative assessment of Parvati Kunda was performed by World Wildlife Fund in 2007 (Manandhar 2007) and surveys focussed on local livelihoods (e.g., Merrey et al. 2018). We, however, could not access any scientific studies from Parvati Kunda that may have characterized the wetland and provide data on biodiversity or water chemistry. As global temperatures rise and human development advances in Gatlang and throughout Nepal, it is critical to establish a baseline in Parvati Kunda now so as to assess the extent and consequences of future changes. Furthermore, such baseline information will characterize the contribution of Parvati Kunda to regional vegetation and bird and macroinvertebrate biodiversity, and ultimately provide information that will promote the sustainable management of the wetland ecosystem.

Study site

Parvati Kunda is in ward number three of Aama Chhodingmo Rural Municipality, about 100km north of Kathmandu in Nepal's Rasuwa District. Climactically, the region is cold and snowy in December through February and temperature maximums occur between May and July. Seasonal climate variations are dominated by the Indian monsoon that occurs between June and September, while small scale climactic variations depend on altitude and aspect (Kharel 1997).

Parvati Kunda is just outside Langtang National Park. The NP encompasses 1,710km^2 (660mi^2) area in Nuwakot, Rasuwa, and Sindhulpalchok districts in the central Himalayan region. Langtang NP and the surrounding area are home to 46 types of mammals and 250 species of birds, including several rare and protected species such as Snow Leopard *Panthera uncia*, Clouded Leopard *Neofelis nebulosi*, Leopard *Panthera pardus*, and Red Panda *Ailurus fulgens* (Fox et al. 1996; DNPWC 2019).

Gatlang Village is located at 2,300m on a trekking route called Tamang Heritage Trail and is known for its traditional Tamang architecture. Most inhabitants of Gatlang identify as Tamang and speak the Tamang language (Merrey et al. 2018). Like other parts of the Langtang region, people grow potato, maize, buckwheat, beans, millet, and barley; raise 'chauri' (Nepali: yak-cow hybrid), sheep, and goats; and run lodges, jeep businesses, or make handicrafts that cater to tourists (Merrey et al. 2018). Gatlang is accessible by road, although there is no regular bus service.

Parvati Kunda (85.261^{o}E & 28.156^{o}N) is a 1.87-hectare groundwater and rainfall/ snowmelt-fed eutrophic wetland located at 2,600m. The wetland is located 300m above Gatlang and lies on the northern edge of Bongjomane Community Forest from which the community members harvest fodder, firewood, and timber. Parvati Kunda is religiously significant and is often the subject of local religious festivals. Water from the deep centre of the wetland is connected to a system of pipes and public taps in the village. Some village taps are fed from one of the three additional springs in the vicinity. Water flows out through a small opening on the northeastern edge of the wetland, where a man-made wall confines the outflow channel to about 1m in width (Fig. 3a). The outflow descends 300m over 1km to Gatlang Village.

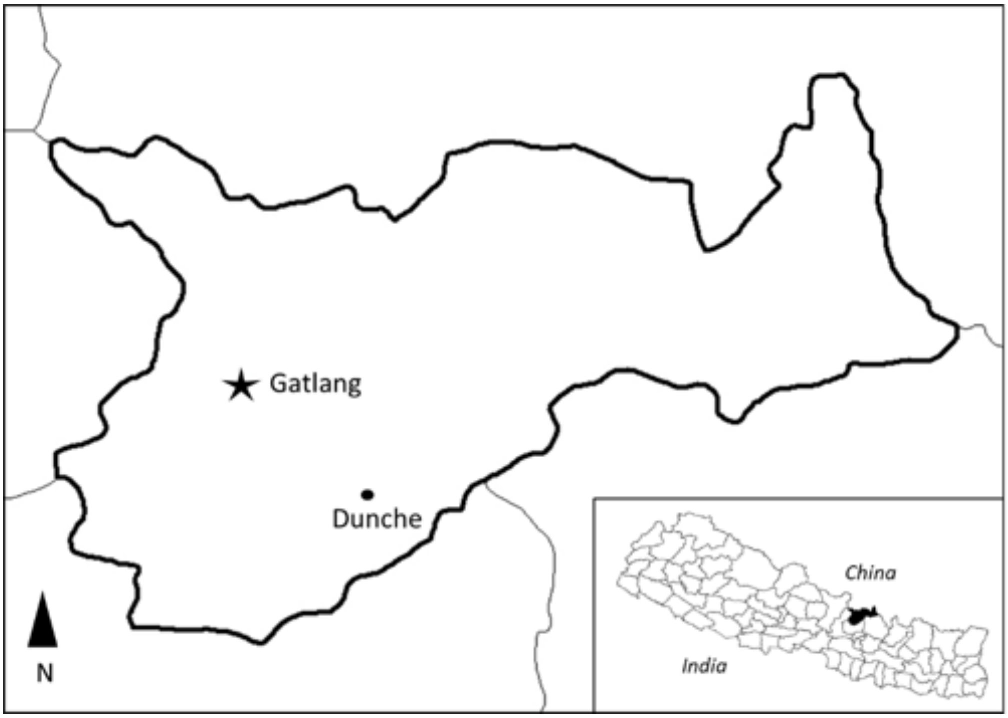

Figure 1. Village Gatlang and Dunche (Dhunche), the administrative seat of Rasuwa District in Nepal (inset).

METHODS

Parvati Kunda was surveyed three times, in November 2016 and in February and May 2017. Surveys for particular taxa groups were conducted when seasonally appropriate. Vegetation and physicochemical parameters were measured in 18 quadrats within the wetland, and others were analyzed in a subset of 10 for macroinvertebrates and 12 nutrient quadrats.

Wetland Vegetation

The locations of vegetation quadrats within Parvati Kunda included the inflow plus 17 randomly determined locations from ArcGIS (ESRI 2014; Fig. 3b). Vegetation surveys included areas that were permanently inundated with emergent or floating macrophytic vegetation, but excluded open water, i.e., the areas inundated but lacking emergent macrophytic vegetation. Open water was excluded from the location generator using satellite imagery and ArcGIS (ESRI 2014; Google Earth 2016). No survey site was more than 0.7m deep and all could be accessed by wading. Vegetation surveys were conducted in November and May only. February was excluded because there was minimal vegetation growth. Quadrat-based sampling was applied to the vegetation study using $0.5m^2$ square quadrats and plants were identified using standard taxonomic keys (Malla et al. 1976). Unidentified species were collected in herbarium sheets for identification by experts at the National Herbarium in Godavari. Per cent cover of each species was visually estimated and the number of individuals of each species was counted. For rhizomous species such as *Juncus leucanthus* or *Acorus calamus*, where multiple shoots might be connected by a single root system, individual shoots were counted to avoid digging up the entire plant. In cases where moss was present, the number of individuals were counted in three 10cm x 10cm sample plots and used to calculate the average number of individuals per square metre. This was used to estimate the number of individuals in quadrats.

Specific information about the proliferation of *A. calamus* in Parvati Kunda over the last 20 years was gathered during conversations with community members. Such local accounts are considered important to understand changes in Parvati Kunda over time since prior published data on wetland vegetation does not exist to the best of our knowledge. Before commencing biodiversity surveys, the researchers interviewed seven high-profile community leaders specifically about water resources in the village. Further insight into questions about changes in Parvati Kunda could be obtained from 31 household surveys that were conducted in conjunction with another study during this time.

Riparian Trees

Four circular riparian tree plots were created on the northern, southwestern, southern, and northeastern sides of the wetland (Fig. 3c). The plots measured 5m in radius, 78.54m^2 in area, covering at least 5% of the riparian area as defined by the wetland boundary wall. Trees with a diameter at breast height greater than 10cm were identified and counted.

Aquatic Macroinvertebrate Survey

Aquatic macroinvertebrate surveys were conducted in May in 10 of the vegetation plots using the pipe method (Britton & Greeson 1989), where a sturdy plastic bucket with a height of 0.81m and diameter 0.288m and no bottom was placed firmly in the mud at each sampling location (Fig. 3d). Using a net, the water inside the bucket was agitated and all insects and loose debris were scooped out with five to six scoops of the net, ensuring that at least three scoops scraped the bottom. Contents of the net were placed in a sieve and excess debris was rinsed and removed in the field. The remaining debris and macroinvertebrates were preserved in 60% ethanol. In the laboratory, invertebrates were sorted, counted, and identified to family level. The Nepal lake biotic index (NLBI) and lake water quality class (LWQC) were calculated using family level identification according to Tachamo-Shah et al. (2011).

Bird Survey

In November, February, and May the point-count method was used for bird observations in which a single observer stayed in one fixed position during a specified period of time and recorded all birds seen or heard during that period (Ralph et al. 1995). This method was used for one hour in the morning and evening. The timings of observations were 07.00–08.00 h and 16.00–17.00 h in May and 08.00–09.00 h and 15.00–16.00 h in November and February, for two consecutive days during each survey period. A single observer stood on the northern bank of the wetland where they had a good view of the entire wetland area with the aid of binoculars.

Wildlife Observation

Data on animals were gathered from direct sighting, evidence of animal usage from faeces, wallows and walking signs, and mentions by local people. Photographic evidence of animals were collected when possible.

Physiochemical Parameters

Physical water parameters were measured in each of 18 quadrats and the outlet in November, February, and May. Measurements for dissolved oxygen, temperature, pH, and electrical conductivity were performed using handheld probes, namely, Lutron DO meter 519, Hanna pHep meter, and Hanna DiST meter. Nitrate, ammonia, and total phosphate were measured at a subset of 12 quadrats (Fig. 3e). To measure nutrients, samples were collected in 500ml clean plastic sample bottles, kept cold, and transported to Kathmandu within 24 hours. Lab work and analysis were performed by CEMAT Water Labs, Kathmandu, Nepal, the procedural references for which are presented in Table 1.

Table 1. Tests and methods used for detection and quantification of nutrients and detection of pathogens. All tests were performed by CEMAT Water Labs in Kathmandu, Nepal.

Test	Method used
Total phosphorus	ISO 6878:1998(E)
Nitrate	ISO 7890-3
Ammonia	4500-NH3 C, APHA 17th Ed.
Total coliform	9221 B, APHA 17th Ed.
E. coli	9221 F, APHA 17th Ed.
Salmonella spp.	9260 B, APHA 17th Ed.
Shigella spp.	9260 E, APHA 17th Ed.
Ova/ worms/ *Giardia*/ amoeba/ cyst	-

Biological Water Quality

Because Parvati Kunda is an important source of drinking water for the Gatlang community, we performed bacterial tests in the wetland and in several other spring-fed water sources and village taps. Using public data on water-borne illnesses from the village health centre to guide our study, we tested for multiple bacterial contaminants, including total coliform, *Escherichia coli, Salmonella, Shigella, Giardia,* and for the possible presence of any ova, worms, cysts, or amoeba. Tests for total coliform, *E. coli, Salmonella*, and *Shigella* were performed in February and May. Tests for *Giardia* and other microscopic stages were done in May. Sampling was performed at three locations in Parvati Kunda—the inlet, the outlet, and WQ1. Tests were also conducted in three additional spring sources, namely, Chyange Spring, Sanglang Ghode Spring, and Shernemba Spring, which supplied water to six village taps (Fig. 4). Water samples were collected in pre-sterilized 250ml collection bottles, kept cold, and transported to Kathmandu within 24 hours. Lab work and analysis was performed by CEMAT Water Labs (Table 1).

Data Analysis

For analysis of wetland vegetation and data from tree surveys, we used density and Simpson's reciprocal index of biodiversity,

$$D = \frac{1}{\frac{\sum n(n-1)}{N(N-1)}}$$

where n = the total number of organisms of a particular species and N = the total number of organisms of all species. The indices were calculated for each quadrat using the vegan package in R (R Development Core Team 2016). Simpson's reciprocal index was used because it tends to be less sensitive to both the shape of the abundance distribution and small sample sizes, compared to other diversity metrics (Gotelli & Chao 2013).

NLBI was calculated by assigning scores to each macroinvertebrate identified according to family. The sum of these scores divided by the number of scored taxa is equivalent to the NLBI. The NLBI score was then translated to a LWQC rating that indicates the degree of pollution likely in the waterbody (Tachamo-Shah et al. 2011).

Total phosphorus was determined using the ammonium molybdate spectrometric method. Ascorbic acid and acid molybdate were added to a 30ml filtered subsample and formed a complex with orthophosphate ions. The complex was then reacted with ascorbic acid to form a blue compound, and the absorbance of this compound was measured against a calibration curve to determine the concentration of orthophosphate in the sample (ISO 6878:1998(E)). Nitrate was measured with the spectrometric method using sulfosalicylic acid. Sodium salicylate and sulfuric acid were added to a 30ml filtered subsample and reacted with nitrate. After alkali treatment, a yellow compound formed. The absorbance of this compound was used to determine the nitrate concentration (ISO 7890-3). The nesslerization method was used to measure ammonia concentration. The water sample was filtered, buffered with a borate buffer, and then distilled into a boric acid solution. Nessler reagent was added to the distillate, reacted with ammonia to produce a yellow colour, and ammonia concentration was measured spectrophotometrically (4500-NH3 C, APHA 17th Ed.).

Total coliform was identified using a fermentation technique. Lauryl tryptose broth was inoculated in fermentation tubes and incubated for 24h at 35^{o}C. If gas or acid was produced, samples were transferred to green lactose bile and incubated for 48h at 35^{o}C. If coliform colonies were observed, samples were transferred to an agar slant and lauryl tryptose broth fermentation tube for 24h at 35^{o}C. If gas was produced at this stage, part of the agar slant growth was gram stained. If gram negative rods were present, coliform was present. Coliform density was estimated by calculating the most probable number (MPN) value from the number of positive green lactose bile tubes (9221 B, APHA 17th Ed.). *Escherichia coli* was identified using the membrane filter method. A quantity of 100mL of sample water was filtered through a 0.45µm pore size membrane filter and placed on a plate of M-endo agar. The plate was incubated at 35^{o}C for 24h and bacterial colonies were inspected for red-metallic colour indicating *E. coli*. Density was estimated with MPN (9221 F, APHA 17th Ed.).

Salmonella and *Shigella* samples were pre-enriched in peptone water, then enriched in tetrathionate broth and incubated at 35^{o}C for 24h. The samples were streaked on *Salmonella Shigella* (SS) agar. The selective solid media allowed plates to be screened for the presence or absence of both *Salmonella* and *Shigella* (9260 B and E, APHA 17th Ed.). Giardia, ova, worms, and cysts were identified by microscopic observation of 100ml of sample for presence/ absence analysis.

RESULTS

Biodiversity Surveys

Vegetation

Twenty-five species of plants were identified from surveys of wetland vegetation (Fig. 3b; Table 2). Surveys also identified a large population of *Sphagnum palustre*, a type of peat moss that is rare in Rasuwa District (Nirmala Pradhan pers. comm. December 2016).

The total area of the wetland dominated by *Acorus calamus* was demarcated by a combination of field measurements on a geographic positioning system (GPS) and visual analysis of satellite imagery in ArcGIS (ESRI 2014; Fig. 3a). *Acorus calamus* covered about 7,140m^2 of the wetland or 38% of the total wetland surface area. Within vegetation survey plots, *A. calamus* covered an average of 37% of the area within the 18 survey quadrats, verifying the visual determination of *A. calamus* coverage in ArcGIS.

Five of seven key informants identified an increase in *A. calamus* and perceived the species as a major threat to the wetland. Sixty-five per cent of respondents in household surveys also identified an increase in *A. calamus* as the most noticeable change in Parvati Kunda over the past 20 years (Yonzon unpub. data).

Nine species of trees were identified during tree

Table 2. Wetland vegetation recorded in Parvati Kunda, Nepal, in 2016–2017.

Order	Family	Scientific name
Acorales	Acoraceae	*Acorus calamus*
Apiales	Apiaceae	*Acronema tenerum*
Asparagales	Orchidaceae	*Spiranthes sinensis*
Asterales	Asteraceae	*Aster tricephalus*
Asterales	Asteraceae	*Pseudognaphalium affine*
Asterales	Asteraceae	*Senecio laetus*
Brassicales	Brassicaceae	*Cardamine flexuosa*
Brassicales	Brassicaceae	*C. impatiens*
Brassicales	Brassicaceae	*C. loxostemonoides*
Caryophyllales	Caryophyllaceae	*Arenaria debilis*
Caryophyllales	Polygonaceae	*Persicaria nepalensis*
Caryophyllales	Polygonaceae	*Persicaria* sp.
Caryophyllales	Polygonaceae	*Rumex nepalensis*
Lamiales	Lamiaceae	*Elsholtzia strobilifera*
Lamiales	Scrophulariaceae	*Hemiphragma heterophyllum*
Lycopodiales	Lycopodiaceae	*Lycopodium japonica*
Malpighiales	Hypericaceae	*Hypericum japonica*
Paeoniales	Paeoniaceae	*Rubus terutleri*
Poales	Juncaceae	*Juncus himalensis*
Poales	Juncaceae	*J. leucanthus*
Poales	Poaceae	*Calamogrostis pseudophragmites*
Poales	Poaceae	*Miscanthus nepalensis*
Ranunculales	Ranunculaceae	*Anemone rivularis*
Ranunculales	Ranunculaceae	*Ranunculus cantoniensis*
Sphagnales	Sphagnaceae	*Sphagnum palustre*

surveys in four different survey plots around the wetland (Fig. 2; Table 3). Tree diversity (Simpson's reciprocal index) ranged from 2.571 on the western side (plot 2) to 4.378 on the eastern side (plot 4) of the wetland.

Macroinvertebrate Surveys

In total, 10 aquatic macroinvertebrate taxa were identified through surveys (Table 4). The NLBI was calculated using these invertebrates to assess the overall ecological quality of the wetland. Parvati Kunda received a 'poor' LWQC rating, indicating a likely high level of nutrient pollution (Tachamo-Shah et al. 2011).

Bird and Mammal Surveys

Point-count bird surveys identified 37 species of birds in and around the wetland (Table 5). Opportunistic observations by the field research team confirmed the presence of six mammal species in or near the wetland area, within 10m from the water's edge. Community members identified four additional mammals that were not directly observed by the researchers (Table 6).

Water Properties

Ammonium and total phosphate levels were mostly negligible (<0.1mg/l). Nitrate was higher at the inlet (2.3mg/l in February and 2.9mg/l in May), but low or negligible in other locations (Table 7). Other parameters including temperature, dissolved oxygen, pH, and electrical conductivity differed over seasons. Average values are presented in Table 8.

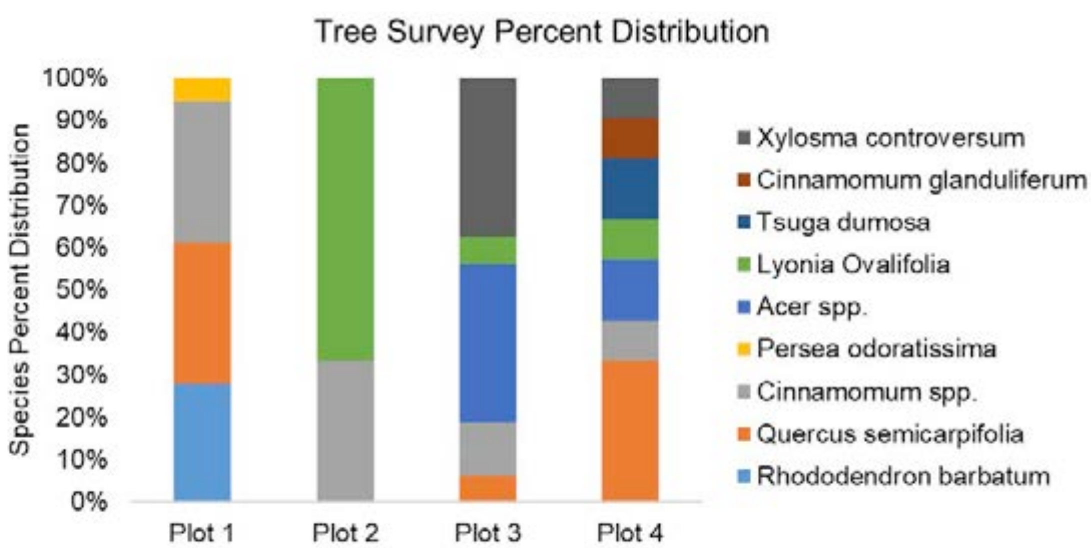

Figure 2. Percent distribution of tree species found around Parvati Kunda, Nepal.

Table 3. Trees found in riparian areas around Parvati Kunda, Nepal, in 2016–2017.

Order	Family	Scientific name	Common name	Plot 1	Plot 2	Plot 3	Plot 4
Ericales	Ericaceae	*Rhododendron barbatum*	Rhododendron	5			
Ericales	Ericaceae	*Lyonia ovalifolia*	Angeri		4	1	2
Fagales	Fagaceae	*Quercus semicarpifolia*	Oak	6		1	7
Laurales	Lauraceae	*Cinnamomum* spp.	Wild Cinnamon	6	2	2	2
Laurales	Lauraceae	*Persea odoratissima*	Pra	1			
Laurales	Lauraceae	*Cinnamomum glanduliferum*	Wild Cinnamon				2
Malpighiales	Salicaceae	*Xylosma controversum*	Willow			6	2
Pinales	Pinaceae	*Tsuga dumosa*	Himalayan Hemlock				3
Sapindales	Sapindaceae	*Acer* spp.	Maple		6	3	
Biodiversity index				**3.306**	**2.571**	**3.267**	**4.378**

Biological Contaminant Tests

Parvati Kunda was found to be contaminated with *E. coli* in both February and May and the *Giardia* trophozoite that is an active stage was found in May. Two out of the three local water sources, namely, Chyange Spring and Shernemba Spring, were contaminated with *E. coli, Giardia, Salmonella, Shigella,* and ova. Compared to water sources, taps generally contained higher levels of *E. coli* and greater variation in other tested contaminants (Table 9).

Table 4. Aquatic macroinvertebrates found in Parvati Kunda, Nepal, in 2016–2017. Two taxa are repeated twice (Haplotaxida: Tubificidae and Coleoptera: Dytiscidae). They represent different species. Identification up to the level of family was needed for NLBI calculation and family was only scored once in NLBI. Trichoptera: Polycentropodidae is not included in the NLBI index score.

	Order	Family	NLBI Score
1	Diptera	Chironomidae	1
2	Haplotaxida	Tubificidae	2
3	Haplotaxida	Tubificidae	Replicate
4	Trichoptera	Polycentropodidae	NA
5	Coleoptera	Dytiscidae	5
6	Odonata	Libellulidae	3
7	Coleoptera	Dytiscidae	Replicate
8	Hemiptera	Corixidae	2
9	Hemiptera	Gerridae	4
10	Veneroida	Sphaeriidae	5
NDBI score/ LWQC rating			3.14/ poor

DISCUSSION

Change in Vegetation Profile

Based on biodiversity surveys, the semi-aquatic plant *Acorus calamus* was by far the most dominant plant species in the wetland. *Sphagnum palustre* is the second most dominant species and is an important structural plant since it influences water chemistry and provides a platform for other plants to grow on (Glime et al. 1982). According to accounts obtained from community members during casual conversation as well as interviews of key informants, the proliferation of *A. calamus* in Parvati Kunda over the past 20 years was high and is a concern for the wetland ecosystem as a source of water for people, animals, and plants.

Monitoring changes in Parvati Kunda vegetation such as *A. calamus* is important because the species composition of wetland macrophytes often reflects water quality. For example, one study in lake Hiidenvesi in Finland identified notable changes in vegetation communities as lake eutrophication progressed—with vegetation changing from species requiring coarse bottom material and high light levels to species favouring soft bottom substrate and turbid waters (Nurminen 2003). Similarly, a study in the Tiber River basin in Italy identified a certain selection of wetland plants as bioindicators of water pollution and eutrophication (Ceschin et al. 2010). *Acorus calamus*, in particular, was identified as especially tolerant to high nitrogen levels and anoxia (Weber & Brändle 1996; Zhang et al. 2018) and therefore the alleged increase in dominance of this species over time in Parvati Kunda could be an indicator of high nitrogen levels and anoxia in the wetland. A study in the Hokersar Wetland in the Kashmir Himalaya in India, however, found that *A. calamus* nearly disappeared in the wetland, which was affected by pollution, siltation, and agriculture and had high levels of nitrogen (Khan

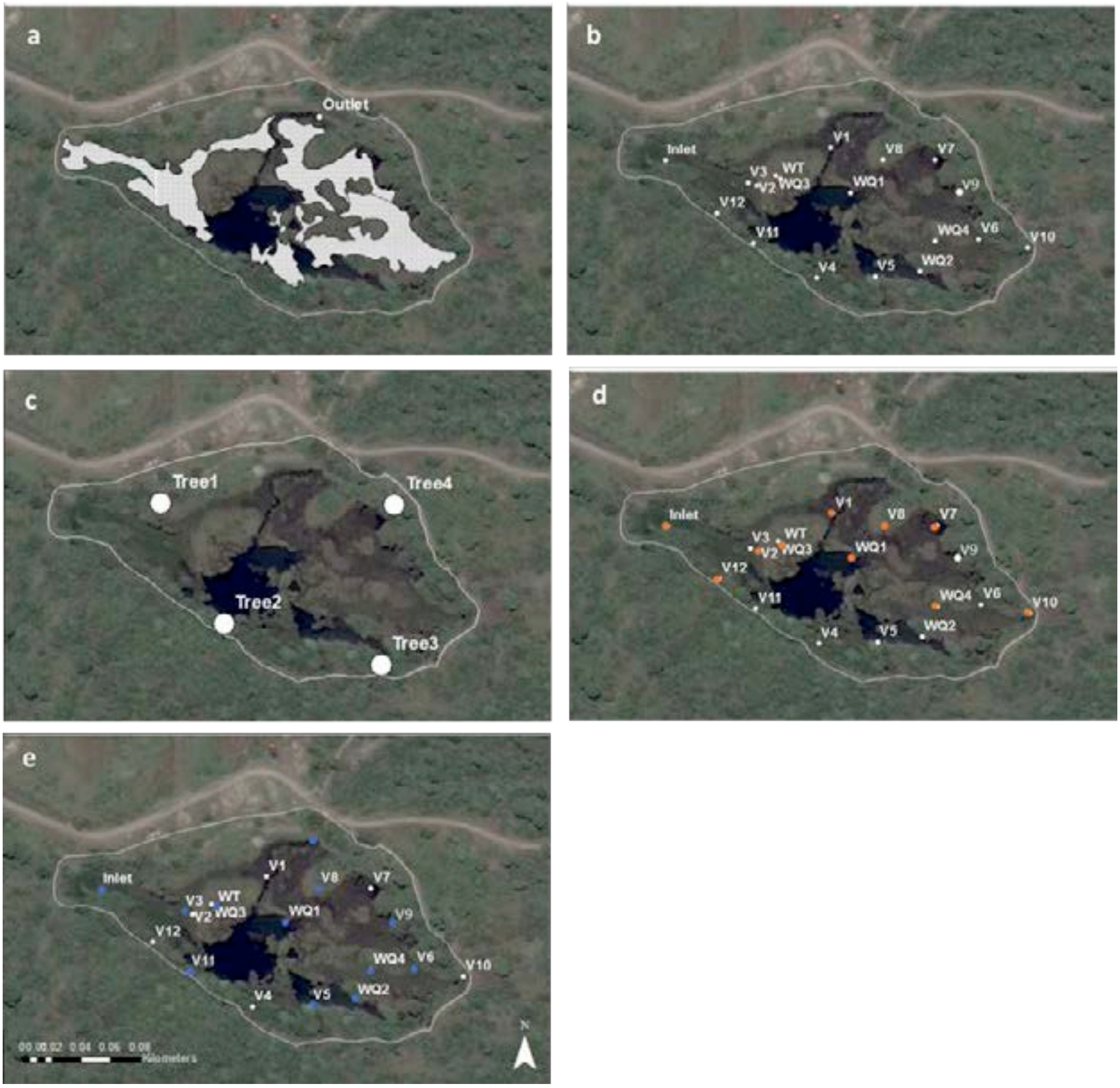

Figure 3. Sampling locations in and around Parvati Kunda, Nepal: a - outlet and *Acorus calamus* growth area | b - vegetation diversity sampling locations | c - tree diversity sampling locations | d - insect diversity sampling locations | e - nutrient sample sites with CEMAT test.

et al. 2004). It is not clear exactly what differences between Hokersar and Parvati Kunda wetlands led to different responses in the *A. calamus* population, but this could be investigated with further study.

Understanding the proliferation of *A. calamus* in Parvati Kunda is also important from the biodiversity perspective. The changes in water quality and associated changes in wetland vegetation can lead to some plant species out-competing others. For example, a long-term study in wetlands in the Jura Mountains in Switzerland found that due to N-deposition, species composition trended towards nutrient-rich flora and some species were out-competed and disappeared from the ecosystem over a period of 25 years (Rion et al. 2018). A similar trend was found at lake Hiidenvesi in Finland, where certain species requiring hard substrates were out-competed by those preferring soft substrates (Nurminen 2003). It is plausible that the proliferation of *A. calamus* identified by local community members could have similar effects on wetland plant diversity and community composition. Although our study did not examine the specific biodiversity impacts of *A. calamus*,

Table 5. Bird species of Parvati Kunda and surrounding areas, Nepal. LC = Least Concern according to IUCN (2016).

Order	Family	Scientific name	Common name	IUCN status
Accipitriformes	Accipitridae	*Spilornis cheela*	Crested Serpent-eagle	LC
Columbiformes	Columbidae	*Streptopelia orientalis*	Oriental Turtle Dove	LC
Cuculiformes	Cuculidae	*Cuculus canorus*	Common Cuckoo	LC
Cuculiformes	Cuculidae	*C. saturatus*	Oriental Cuckoo	LC
Galliformes	Phasianidae	*Francolinus francolinus*	Black Francolin	LC
Gruiformes	Rallidae	*Zapornia bicolor*	Black Tailed Crake	LC
Passeriformes	Aegithalidae	*Aegithalos concinnus*	Black-throated Tit	LC
Passeriformes	Cettiidae	*Horornis flavolivacea*	Aberrant Bush Warbler	LC
Passeriformes	Corvidae	*Corvus macrorhynchos*	Large-billed Crow	LC
Passeriformes	Corvidae	*Pyrrhocorax pyrrhocorax*	Red-billed Chough	LC
Passeriformes	Corvidae	*Urocissa flavirostris*	Yellow-billed Blue Magpie	LC
Passeriformes	Dicruridae	*Dicrurus leucophaeus*	Ashy Drongo	LC
Passeriformes	Fringillidae	*Carduelis spinoides*	Yellow-breasted Greenfinch	LC
Passeriformes	Fringillidae	*Carpodacus thura*	White-browed Rosefinch	LC
Passeriformes	Laniidae	*Lanius schach*	Long-tailed Shrike	LC
Passeriformes	Laniidae	*L. tephronotus*	Grey-backed Shrike	LC
Passeriformes	Leiothrichidae	*Trochalopteron lineatum*	Streaked Laughingthrush	LC
Passeriformes	Leiothrichidae	*T. variegatum*	Variegated Laughingthrush	LC
Passeriformes	Leiothrichidae	*Heterophasia capistrata*	Rufous Sibia	LC
Passeriformes	Motacillidae	*Anthus* spp.	Pipit spp.	-
Passeriformes	Motacillidae	*Motacilla cinerea*	Grey Wagtail	LC
Passeriformes	Muscicapidae	*Enicurus maculatus*	Spotted Forktail	LC
Passeriformes	Muscicapidae	*Ficedula westermanni*	Little Pied Flycatcher	LC
Passeriformes	Muscicapidae	*Myophonus caeruleus*	Blue Whistling-thrush	LC
Passeriformes	Muscicapidae	*Phoenicurus frontalis*	Blue-fronted Redstart	LC
Passeriformes	Muscicapidae	*Saxicola ferreus*	Grey Bushchat	LC
Passeriformes	Muscicapidae	*S. torquatus*	Common Stonechat	LC
Passeriformes	Paridae	*Lophophanes dichrous*	Grey-crested Tit	LC
Passeriformes	Paridae	*Parus monticolus*	Green-backed Tit	LC
Passeriformes	Pycnonotidae	*Pycnonotus leucogenys*	Himalayan Bulbul	LC
Passeriformes	Sittidae	*Sitta himalayensis*	White-tailed Nuthatch	LC
Passeriformes	Stenostiridae	*Culicicapa ceylonensis*	Grey-headed Canary-flycatcher	LC
Passeriformes	Sylviidae	*Fulvetta vinipectus*	White-browed Fulvetta	LC
Passeriformes	Timaliidae	*Pomatorhinus erythrogenys*	Rusty-cheeked Scimitar-babbler	LC
Passeriformes	Troglodytidae	*Troglodytes troglodytes*	Northern Wren	LC
Passeriformes	Turdidae	*Turdus unicolor*	Tickell's Thrush	LC
Piciformes	Picidae	*Picus squamatus*	Scaly-bellied Woodpecker	LC

future studies in Parvati Kunda should make use of the baseline information presenting possible threats here to understand the consequences of *A. calamus* growth within the wetland ecosystem.

Given the dominance of *A. calamus* in Parvati Kunda, we expected to find high levels of nutrients in water samples. This was not the case and nutrient levels were, in most cases, negligible. Since *A. calamus* grows both in water and on wetland edges or areas that are not permanently inundated, however, soil could be another critical source of excess nutrients. For example, a study on residual availability of nitrogen in soil following

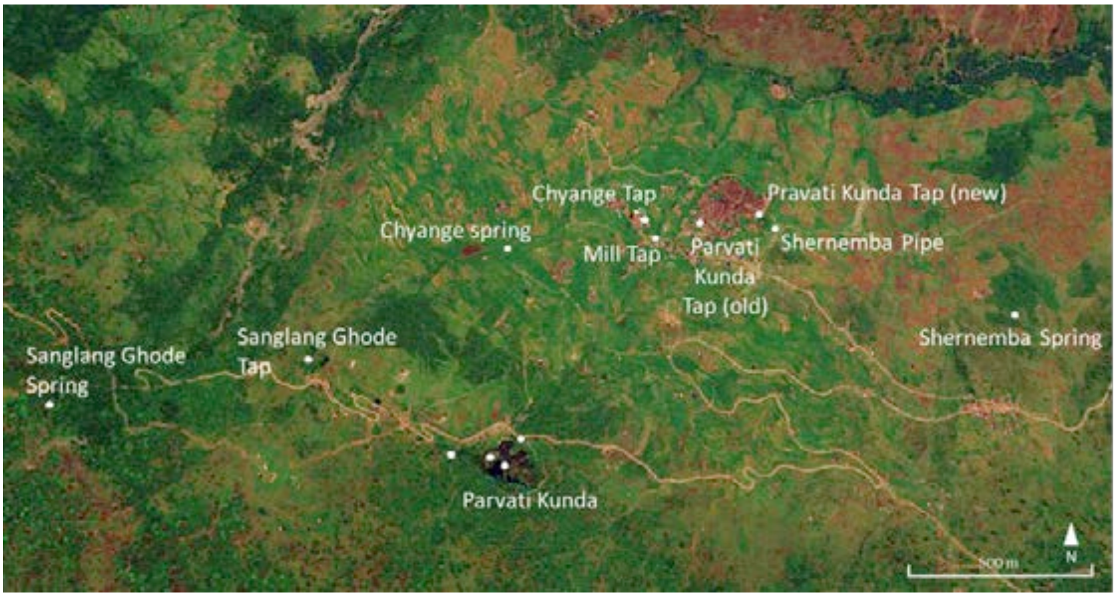

Figure 4. Four water sources tested for microorganism contamination (Sanglang Ghode, Chyange, Parvati Kunda, and Shernemba) and taps tested in the village. Three sites (inlet, outlet, and WQ1) were tested within Parvati Kunda, Nepal (Table 9).

Table 6. Mammal species occurring around Parvati Kunda, Nepal, in 2016–2017. LC = Least Concern and V = Vulnerable according to IUCN (2018).

Taxa	Scientific name	Direct observation	Secondary information	IUCN status
Nepal Grey Langur	*Semnopithecus schistaceus*	x		LC
Barking Deer	*Muntiacus muntjak*	x		LC
Royles Pika	*Ochotona roylei*	x		LC
Yellow-throated Marten	*Martes flavigula*	x		LC
Chauri	-	x		-
Goats/ Sheep	-	x		-
Porquipine	*Hystrix* spp.		x	-
Leopard	*Panthera pardus*		x	V
Mongoose	*Herpestes* spp.		x	-
Wild Boar	*Sus scrofa*		x	LC

Table 7. Total phosphorus, nitrate, and ammonia measurements for February (10 wetland locations, see Fig. 3e) and May (three wetland locations—outlet, inlet, and WQ3). Fields in this table represent a single data point; only one sample was taken in each location in each season.

Sample location	T. phosphorus (mg/l as P)		Nitrate (mg/l as NO_3)		Ammonia (mg/l as NH_3)	
	February	May	February	May	February	May
Outlet	<0.1	<0.1	<0.1	0.3	<0.1	<0.1
Inlet	<0.1	<0.1	2.3	2.9	<0.1	<0.1
WQ1	<0.1		0.7		<0.1	
WQ2	<0.1		0.4		<0.1	
WQ3	<0.1	<0.1	<0.1	0.4	<0.1	0.8
WQ4	<0.1		<0.1		<0.1	
V3	<0.1		0.1		<0.1	
V5	<0.1		<0.1		<0.1	
V6	<0.1		0.5		0.1	
V8	<0.1		<0.1		<0.1	
V9	<0.1		<0.1		<0.1	
V10	<0.1		0.1		<0.1	
V11	<0.1		0.7		<0.1	

Table 8. Temperature, dissolved oxygen, pH, and electrical conductivity in 18 sampling locations in the wetland. Averages and standard deviations (SD) from the three sample points (November 2016 and February and May 2017) are presented. Note: pH was measured only in February and May and conductivity was measured only in November and February.

Sample location	Temperature (°C)		Dissolved oxygen (mg/l)		pH		Conductivity (mg/l)	
	Average	SD	Average	SD	Average	SD	Average	SD
Outlet	13.0	2.6	7.4	0.6	7.0	0.5	30.0	0.0
Inlet	12.2	0.6	7.3	0.5	6.2	0.3	20.0	0.0
WQ1	15.5	4.3	5.8	1.2	6.8	0.4	30.0	0.0
WQ2	14.7	6.3	5.5	3.1	5.9	1.0	20.0	0.0
WQ3	20.9	4.1	9.0	6.5	7.0	1.1	20.0	10.0
WQ4	13.9	8.8	8.4	0.7	6.1	0.4	20.0	0.0
WT	15.8	3.5	2.1	1.2	4.5	0.3	10.0	0.0
V1	13.7	2.1	9.4	0.9	6.8	0.4	30.0	0.0
V2	18.0	0.7	10.8	5.8	6.4	1.1	20.0	0.0
V3	16.7	7.0	5.3	2.9	5.9	0.8	30.0	10.0
V4	12.7	4.0	5.5	1.7	5.7	1.1	20.0	0.0
V5	13.4	6.9	6.0	3.2	6.6	0.6	25.0	5.0
V6	14.2	7.7	7.9	1.1	6.4	0.4	20.0	0.0
V7	18.0	10.1	6.7	2.3	6.6	0.2	35.0	5.0
V8	14.0	8.6	7.6	1.2	6.8	0.2	30.0	0.0
V9	14.9	10.2	7.9	0.9	7.0	0.5	30.0	0.0
V10	12.6	9.0	5.6	1.6	5.7	0.5	5.0	5.0
V11	12.8	3.5	5.3	0.3	6.7	0.8	40.0	0.0
V12	10.0	6.6	5.4	1.8	5.9	0.9	20.0	0.0

application of organic fertilizer from farmyard manure or compost found that nitrogen can be immobilized in soils and enrich the soil nitrogen pool over a long term (Gutser et al. 2005). A similar phenomenon may happen near Parvati Kunda, leading to slow release of nitrogen from the soil rather than from the water. Furthermore, nutrient addition studies on invasive *Phragmites australis* in the United States found that nitrogen added to soil, rather than water, significantly increased the growth of the wetland plant *P. australis* compared to the native *Spartina pectinata* (Rickey & Anderson 2004). This indicates that nutrient enrichment of soil can indeed increase growth rates of wetland plants. Additionally, *A. calamus* itself might absorb much of the nitrogen entering the wetland. Zhang et al. (2018) investigated the nitrite stress tolerance of *A. calamus* during wastewater treatment and found that *A. calamus* could tolerate up to 30mg/l of nitrite (2018). Likewise, a study in northeastern China identified *A. calamus* as a tool for nitrogen removal in floating treatment wetlands, finding that *A. calamus* demonstrated an 84.2% removal efficiency for total nitrogen (Li & Guo 2017). Thus, ensuing studies on *A. calamus* in Parvati Kunda should focus on the nutrient content of both *A. calamus* and the soil to fully understand the nutrient dynamics in the wetland.

Nutrient pollution and microorganisms

The presence of excess nutrients in Parvati Kunda is also indicated by the 'poor' LWQC score, which suggests a 'heavy' degree of nutrient pollution (Tachamo-Shah et al. 2011). This rating is related to the diversity and types of macroinvertebrates present in the wetland. Several direct explanations for a poor rating may exist; for example, lack of substrate and lack of dissolved oxygen as a result of excess nutrient inputs and eutrophication processes can inhibit macroinvertebrate breeding, emergence, and overall survival (Boles 1981; Connolly et al. 2004). When abiotic conditions such as nutrient levels, substrate type, and dissolved oxygen are unfavourable, the rest of the ecosystem is affected. It should be noted, however, that although Parvati Kunda received a poor rating, the pipe method used for macroinvertebrate sampling was quantitative instead

Table 9. Results of tests conducted in February and May 2017 for presence (P) or absence (A) of microorganism per 100ml of water samples from 12 different locations near Parvati Kunda, Nepal. MPN Index stands for most probable number of colonies present in 100ml of sample, which is determined by comparing the pattern of positive results with statistical tables (Bartram & Pedley 1996). Key to sample locations (Fig. 4): 1 - PK Inlet, 2 - PK Outlet, 3 - PK WQ1, 4 - Chyange Spring, 5 - Chyange Tap, 6 - Sanglang Ghode Spring, 7 - Sanglang Ghode Tap, 8 - Shernemba Spring, 9 - Shernemba Pipe, 10 - Mill Tap, 11 - Old Parvati Kunda Tap, 12 - New Parvati Kunda Tap.

Sample location	Total coliform (MPN index/100ml)		*E. coli* (MPN index/100ml)		*Salmonella* spp. (P/A)*		*Shigella* spp. (P/A)*		Ova (P/A)*		Worms (P/A)*		*Giardia* (P/A)*		Amoeba (P/A)*		Cyst (P/A)*	
	Feb	May	Feb	May	Feb	May	Feb	May	Feb	May	Feb	May	Feb	May	Feb	May	Feb	May
1	9	150	4	9	-	A	-	A	-	A	-	A	-	A	-	A	-	A
2	0	1100	0	460	A	A	A	A	-	A	-	A	-	A	-	A	-	A
3	-	210	-	39	-	A	-	A	-	A	-	A	-	***P***	-	A	-	A
4	93	23	43	4	***P***	A	***P***	***P***	-	***P***	-	A	-	A	-	A	-	A
5	-	4	-	4	-	A	-	A	-	A	-	A	-	A	-	A	-	A
6	-	0	-	0	-	A	-	A	-	A	-	A	-	A	-	A	-	A
7	-	1100	-	43	-	A	-	***P***	-	A	-	A	-	A	-	***P***	-	A
8	-	240	-	43	-	A	-	A	-	A	-	A	-	A	-	A	-	A
9	-	240	-	43	-	A	-	A	-	A	-	A	-	A	-	A	-	***P***
10	460	1100	240	240	***P***	A	***P***	A	-	A	-	A	-	A	-	***P***	-	A
11	43	1100	15	460	-	A	-	A	-	A	-	A	-	A	-	A	-	A
12	23	240	3	93	-	A	-	A	-	A	-	A	-	A	-	A	-	A

of qualitative as the NLBI method suggests (Tachamo-Shah et al. 2011). Even if a more extensive qualitative survey were conducted, however, the LWCQ rating would most likely only move one step from poor to fair. This would still indicate a moderate level of nutrient pollution. Furthermore, wetlands in monsoonal systems such as in Nepal are known to change in water quality ranking depending on the season. For example, a study in the Rampur Ghol ecosystem in Chitwan, Nepal, used a similar macroinvertebrate indicator system to describe water quality and found that water quality and macroinvertebrate diversity was generally lower in the dry season than the rainy season (Gautam et al. 2014). Likewise, the LWCQ rating in Parvati Kunda probably fluctuates throughout the year and additional qualitative sampling would possibly identify either poor or fair ratings depending on the season.

Several of the macroinvertebrate taxa identified in this study indicate specific details about Parvati Kunda and its level of pollution. For example, many prior studies found that Chironomidae abundance generally increases with decreasing habitat quality (Fore et al. 1996; Botts 1997) and red Chironomidae are easily identifiable and are therefore a good indicator of this pattern (Tachamo-Shah et al. 2011). Red Chironomidae was very abundant at all sampling locations within Parvati Kunda, indicating high levels of pollution. Furthermore, various species in Insecta families of Heteroptera and Corixidae were used as indicators of eutrophication and pollution in Finland (Jansson 1977). As the Finland study found, species within the Corixidae family vary greatly in their tolerance to pollution, they were assigned a low rating (2) in the NLBI, and their presence in Parvati Kunda indicates high levels of nutrient pollution that may be specifically linked to eutrophication.

Threat of Eutrophication

Although wetland eutrophication is a natural process, it is unclear whether human activities within the Parvati Kunda watershed may also be influencing degradation of the wetland. Activities such as agriculture, livestock raising, and timber harvesting within the wetland watershed may lead to higher levels of nutrient inputs that could explain the patterns we observed in Parvati

Kunda (Foote et al. 1996; Prasad et al. 2002). Most of the Kunda watershed is encompassed by Bongjomane Community Forest, which is utilized by Gatlang community members for fodder and timber harvesting. Livestock also inhabits the area around the wetland. Future studies should use GIS and satellite imageries to assess landuse changes in the Parvati Kunda watershed over the last 30 years. Such a study could help indicate how and why nutrient pollution occurred in the wetland.

Public records available at the village health centre showed persistent infections of intestinal worms, Salmonellosis, and Shigellosis, and we indeed found associated contaminants in Parvati Kunda, three alternative water sources, and several village taps. Of all water sources and taps tested, only one water source at Sanglang Ghode spring was in compliance of Nepal national drinking water quality standards (Ministry of Physical Planning and Works 2005). Livestock waste is a probable source of contamination in the wetland itself, especially since livestock was frequently observed inside the wetland enclosure and was observed defecating near the water during bacterial sampling. Other reasons for contamination may include leaking pipes through which contaminants can seep between the water source and village taps. The extent and source of bacterial contamination in the wetland, other water sources, pipes, and taps should be further investigated, and methods for maintaining acceptable drinking water quality in the village should be pursued.

CONCLUSION

The present study is a baseline study in the Parvati Kunda Wetland and is believed to provide the first description of its wetland vegetation, riparian trees, aquatic macroinvertebrates, birds, physiochemical water parameters, and biological contaminants. Our data indicate a moderate to heavy degree of nutrient pollution, although the direct and indirect causes and consequences of pollution are not fully understood. Continued monitoring of the Parvati Kunda wetland will provide a valuable and interesting example of the process of wetland degradation and conservation in the Nepal Himalaya.

Future studies should focus on amphibian- and mammal-specific surveys. Additionally, watershed level studies that describe land-use changes and may indicate reasons for wetland degradation are necessary.

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Diversity and community structure of Odonata (Insecta) in two land use types in Purba Medinipur District, West Bengal, India

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Abstract: The present study recorded a total of 45 species of Odonata, of which one species, *Ischnura mildredae*, was recorded for the first time from West Bengal in India. Thirty-eight species were found in Tamluk Municipality as compared to 21 species in Haldia Industrial Belt (IB), with 14 species common to both the localities. Index of similarity revealed that the two localities were slightly dissimilar in odonate faunal composition as only 47% of species were shared. In both the localities, Anisoptera was more abundant, comprising over 69% of the total odonates. Libellulidae was the most abundant Anisopteran family in both the localities, comprising over 66% of the total odonates. Coenagrionidae was the most abundant Zygopteran family in both the localities. Thirteen species of Anisoptera and 11 species of Zygoptera were found only in Tamluk whereas two species of Anisoptera and five species of Zygoptera were found only in Haldia IB. *Crocothemis servilia*, *Pantala flavescens*, and *Ceriagrion coromandelianum* were the dominant species in Tamluk while *Brachythemis contaminata* and *Orthetrum sabina* were the dominant species in Haldia IB. Based on the values of Shannon index, Tamluk was considered unpolluted (=3.16) and Haldia IB moderately polluted (=2.43). Higher equitability index (J=0.87) and very low dominance index (0.06) in Tamluk indicated homogeneity in community composition and relatively stress-free equitable environment. The present investigation suggests that Odonata can be used as bioindicators of industrial pollution.

Keywords: Anisoptera, Coenagrionidae, dominance index, ecological indicator, equitability index, Haldia Industrial Belt, Libellulidae, Shannon index, Tamluk Municipality, Zygoptera.

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Author Contribution: PRP designed the research work and contributed in writing. SSM has contributed in field work, data collection & documentation. SM has also contributed in field work, data collection, documentation and preparation of graphs & tables for manuscript. TB has contributed in data analysis, interpretation & write-up and overall supervision.

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INTRODUCTION

Odonates play a crucial role in ecosystem stability and act as indicators of environment changes since the larvae of some species are sensitive to pollutants (Villalobos-Jimenez et al. 2016). Being predators both in aquatic and aerial lives, these are good bio-controlling agents for mosquitoes and blood-sucking flies (Nair 2011). The order Odonata includes 6,256 species under 686 genera worldwide, of which 487 species under 152 genera and 18 families are found in India (Subramanian & Babu 2017). Early taxonomy of Indian Odonata was provided by Fraser (1933, 1936). Odonates of West Bengal were studied by Ram et al. (1982), Srivastava & Sinha (1993), and Mitra (2002). Srivastava & Sinha (1993) recorded 178 species of odonates from West Bengal. In the present study, odonate fauna under two land use types, a semi-urban area and an industrial area, was investigated to explore how human alteration of environment may influence the density and diversity of odonate species.

MATERIALS AND METHODS

The present study was carried out in two different localities representing different land use types (Fig. 1) from July to December 2017. Samples were collected fortnightly between 10.00–16.00 h. The first study site, the district town of Tamluk, is a semi-urban municipal area (22.260–22.304 ^{0}N & 87.902–87.935 ^{0}E, altitude 6m, average rainfall 1,550mm, temperature 13.6–35.6 ^{0}C) harbouring many small water bodies, most of which are fish ponds studded with aquatic weeds. The town is located on the bank of the river Rupnarayana. Small canals and tributaries of Rupnarayana are the main lotic systems of the area. The second locality, Haldia Industrial Belt (IB; 22.029–22.093 ^{0}N & 88.085–88.181 ^{0}E, altitude 8m, average rainfall 1,450mm, temperature 14.1–34 ^{0}C), is an industrial area with a port located at the junction of the rivers Hoogly and Haldi. Indian Oil Corporation Ltd., Haldia Petrochemicals Ltd., TATA Chemicals Ltd., Emami Biotech Ltd., Mistubisi Chemical Corporation, Exide Industries Ltd., Shaw Wallace India

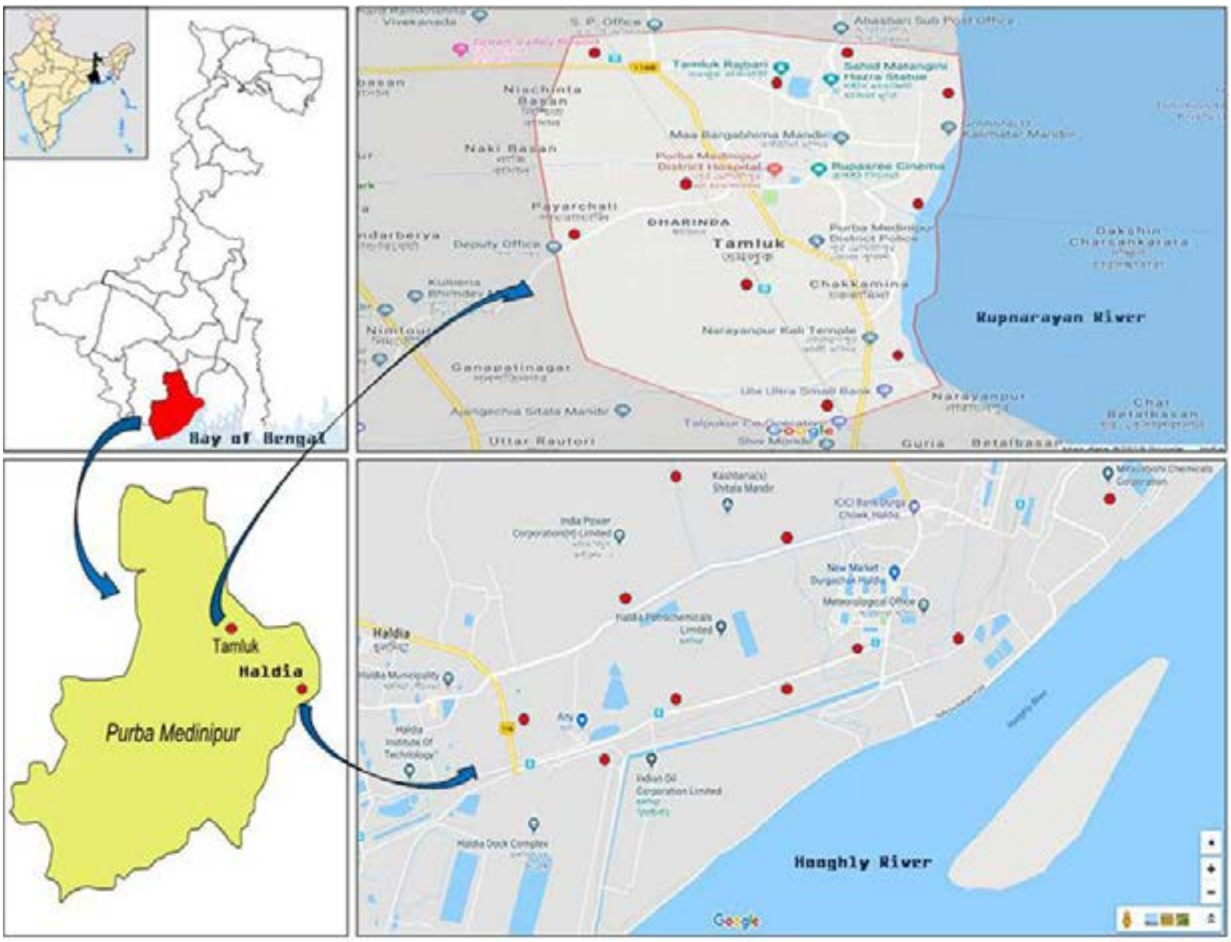

Figure 1. Study sites with sampling locations in Purba Medinipur District, West Bengal, India.

Ltd., Electrosteel Casting Ltd., Shree Renuka Sugars Ltd., and Dhunseri Petrochem & Tea Ltd. are the main industries in this area. According to a report of the West Bengal Pollution Control Board (2009–2010), Haldia IB has a very high concentration of air pollutants like SO_x, NO_x, CO, CO_2 and O_3. Both localities are situated at an aerial distance of only 32km. From each locality, 10 sampling sites were selected representing different habitats.

Collection, preservation, documentation, and identification

Adult odonates were sampled from each study site using insect nets. Quantitative measurements of odonates were done through the line transect method following Burnham et al. (1980). Specimens were photographed with a digital camera (Sony HX200V). Species were identified following Subramanian (2005) and also by using the webpage indiaodonata.org. The Odonate community structure was analyzed with the help of PAST software. The dominance status of each species was ascribed on the basis of relative abundance following Engelmann's Scale (Engelmann 1973). Faunal similarity or otherwise between the localities was determined using Sørensen's index (Sørensen 1948).

RESULT AND DISCUSSION

Forty-five species of Odonata were recorded under two suborders and six families from the study sites. Of these, one species, *Ischnura mildredae*, was recorded for the first time from West Bengal and five species, namely, *Neurothemis intermedia, Aciagrion pallidum*, *Agriocnemis lacteola*, *A. pieris*, and *Ceriagrion olivaceum* were reported for the first time from Purba Medinipur District (Table 1). Tamluk, an area with many weed infested waterbodies, had 38 species as compared to 21 species in Haldia IB, with 14 species common to both the localities. Sørensen's Index of similarity being 0.47 indicates that 47% of species are common and that the two localities are slightly dissimilar in odonate species composition.

While 23 species of Anisoptera and 15 species of Zygoptera were recorded from Tamluk, 12 species of Anisoptera and nine species of Zygoptera were recorded from Haldia IB. Interestingly, in Haldia IB, the families Gomphidae and Macromiidae were absent, which were represented by one species each in Tamluk. A higher number of species recorded from a less disturbed area and a lower number of species from a more disturbed industrial area as found in this study is supported by the earlier works of Allen et al. (2010), Subramanian (2010), and Nayak & Roy (2016). Tiple & Koparde (2015) opined that aquatic vegetation has a regulatory role in the faunal distribution of Odonata. This might explain the higher numbers of species in Tamluk. In Tamluk and Haldia IB, Anisoptera was numerically more abundant comprising 69.5% and 77.3% as compared to Zygoptera which comprised 30.5% and 22.7%, respectively (Fig. 2).

The peponderance of Anisoptera over Zygoptera as in the present study was also reported by Manwar et al. (2016) in Maharashtra, who accounted this to be due to their higher dispersal ability, wide range of habitat preferences, and higher tolerance level as compared to Zygoptera. Moore (1957), however, was of the view that dragonflies are more sensitive to pollutants than damselflies. In Tamluk and Haldia IB, Libellulidae, with 19 and 11 species, respectively, was the most abundant Anisopteran family, representing 66.2% and 76.6% of the total odonates (Fig. 3).

Such a preponderance of Libellulidae over other families was also well-established in different regions of India by earlier works, namely that of Arulprakash & Gunathilagaraj (2010), Tiple et al. (2012), and Nayak & Roy (2016). In both Tamluk and Haldia IB, Coenagrionidae was the most common Zygopteran family with 13 and eight species, respectively, representing 27.2%

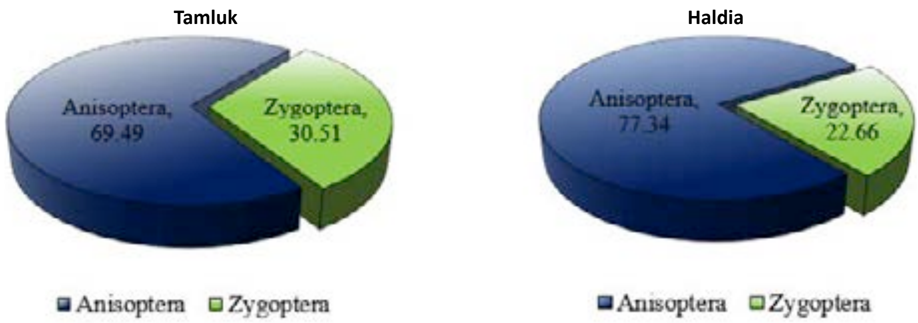

Figure 2. Relative abundance of Anisoptera and Zygoptera in Tamluk Municipality and Haldia Industrial Belt in Purba Medinipur District, West Bengal, India.

Table 1. Diversity of Odonata in Tamluk Municipality and Haldia Industrial Belt in Purba Medinipur District, West Bengal, India.

	Scientific name	Tamluk	Haldia
Suborder: Anisoptera			
Family: Aeshnidae			
1	*Anaciaeschna jaspidea* (Burmeister, 1839)	+	-
2	*Anax guttatus* (Burmeister, 1839)	-	+
3	*Gynacantha dravida* (Lieftinck, 1960)	+	-
Family: Gomphidae			
4	*Ictinogomphus rapax* (Rambur, 1842)	+	-
Family: Libellulidae			
5	*Acisoma panorpoides* (Rambur, 1842)	+	-
6	*Brachydiplax chalybea* (Brauer, 1868)	-	+
7	*B. sobrina* (Rambur, 1842)	+	+
8	*B. contaminata* (Fabricius, 1793)	+	+
9	*Crocothemis servilia* (Drury, 1770)	+	+
10	*Diplacodes nebulosa* (Fabricius, 1793)	+	-
11	*D. trivialis* (Rambur, 1842)	+	+
12	*Neurothemis fulvia* (Drury, 1770)	+	-
13	*N. intermedia* (Rambur, 1842)**	+	-
14	*N. tullia* (Drury, 1770)	+	+
15	*Orthetrum sabina* (Drury, 1770)	+	+
16	*Pantala flavescens* (Fabricius, 1798)	+	+
17	*Potamarcha congener* (Rambur, 1842)	+	+
18	*Rhodothemis rufa* (Rambur, 1842)	+	-
19	*R. variegata* (Linnaeus, 1763)	+	+
20	*Tholymis tillarga* (Fabricius, 1798)	+	-
21	*Tramea basilaris* (Palisot de Beauvois, 1805)	+	-
22	*Trithemis pallidinervis* (Kirby, 1889)	+	-
23	*Urothemis signata* (Rambur, 1842)	+	+
24	*Zyxomma petiolatum* (Rambur, 1842)	+	-
Family: Macromiidae			
25	*Epophthalmia vittata* (Burmeister, 1839)	+	-
Suborder: Zygoptera			
Family: Coenagrionidae			
26	*Aciagrion pallidum* (Selys, 1891)**	-	+
27	*Agriocnemis kalinga* (Nair & Subramanian, 2014)	-	+
28	*A. lacteola* (Selys, 1877)**	+	-
29	*A. pieris* (Laidlaw, 1919)**	+	-
30	*A. pygmaea* (Rambur, 1842)	+	+
31	*Ceriagrion cerinorubellum* (Brauer, 1865)	+	+
32	*C. coromandelianum* (Fabricius, 1798)	+	+
33	*C. olivaceum* (Laidlaw, 1914)**	+	-
34	*Ischnura aurora* (Brauer, 1865)	+	-
35	*I. mildredae* (Fraser, 1927)*	-	+
36	*I. rubilio* (Selys, 1876)	+	-
37	*I. senegalensis* (Rambur, 1842)	+	+
38	*Mortonagrion aborense* (Laidlaw, 1914)	+	-
39	*Onychargia atrocyana* (Selys, 1877)	-	+
40	*Pseudagrion decorum* (Rambur, 1842)	+	-
41	*P. microcephalum* (Rambur, 1842)	+	-
42	*P. rubriceps* (Selys, 1876)	+	-
Family: Platycnemididae			
43	*Copera ciliata* (Selys, 1863)	-	+
44	*C. marginipes* (Rambur, 1842)	+	-
45	*C. vittata* (Selys, 1863)	+	-
Sørensen's similarity index = 0.47			

[* first report from West Bengal; ** first report from Medinipur]

and 21.96% of the total odonates. Large body size and wide range of distribution might be the reason behind this as suggested by Norma-Rashid et al. (2001). Members of the families Macromiidae and Gomphidae were recorded only from Tamluk. These families are highly habitat-sensitive and localized to small areas as pointed out by Subramanian (2005) and Koparde et al. (2015). The 14 species common to both the study sites (Table 1) perhaps have a broad range of tolerance gradient. Two dragonfly species, *Anax guttatus and Brachydiplax chalybea, and five damselfly species, namely, Aciagrion pallidum, Agriocnemis kalinga, Ischnura mildredae, Onychargia atrocyana,* and *Copera ciliata,* were restricted to Haldia IB. As such, these species might be considered to be pollution-tolerant. Thirteen species of Anisoptera and 11 species of Zygoptera were found only in Tamluk Municipality. These species might be considered sensitive to pollutants. Jana et al. (2006) also reported some species of Lepidoptera, Hemiptera, and Orthoptera which were susceptible to pollutants and not found in Haldia IB. Based on relative abundance (Table 2), it was found that in Tamluk, three species, namely, *Pantala flavescens, Crocothemis servilia,* and *Ceriagrion coromandelianum,* were dominant (RA 10.1–31.6 %) and six species were subdominant (RA 3.2–10 %). The rest were either recedent (17 species) or subrecedent (12 species). In Haldia IB, two species, namely, *Orthetrum sabina* and *Brachythemis contaminata*, were dominant, eight species were subdominant, and the rest were recedent and subrecedent (Table 3). In the present investigation, no species belonged to the eudominant category.

Subramanian et al. (2008) opined that the presence

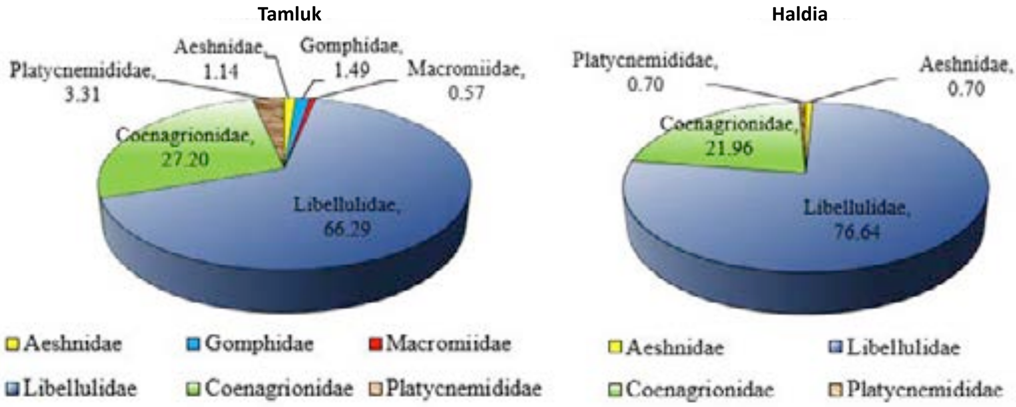

Figure 3. Relative abundance of odonate families in Tamluk Municipality and Haldia Industrial Belt in Purba Medinipur District, West Bengal, India.

Table 2. Dominance status of odonate species in Tamluk Municipality in Purba Medinipur District, West Bengal, India.

	Scientific name	No. of individuals	Relative abundance (%)	Dominance status
Suborder: Anisoptera				
Family: Aeshnidae				
1	*Anaciaeschna jaspidea*	6	0.69	SR
2	*Gynacantha dravida*	4	0.46	SR
Family: Gomphidae				
3	*Ictinogomphus rapax*	13	1.49	R
Family: Libellulidae				
4	*Acisoma panorpoides*	17	1.94	R
5	*Brachydiplax sobrina*	23	2.63	R
6	*Brachythemis contaminata*	35	4.00	SD
7	*Crocothemis servilia*	97	11.09	D
8	*Diplacodes nebulosa*	13	1.49	R
9	*D. trivialis*	61	6.97	SD
10	*Neurothemis fulvia*	17	1.94	R
11	*N. intermedia*	8	0.91	SR
12	*N. tullia*	48	5.49	SD
13	*Orthetrum sabina*	13	1.49	R
14	*Pantala flavescens*	126	14.40	D
15	*Potamarcha congener*	19	2.17	R
16	*Rhodothemis rufa*	9	1.03	R
17	*R. variegata*	24	2.74	R
18	*Tholymis tillarga*	28	3.20	SD
19	*Tramea basilaris*	7	0.80	SR
20	*Trithemis pallidinervis*	11	1.26	R
21	*Urothemis signata*	18	2.06	R
22	*Zyxomma petiolatum*	6	0.69	SR
Family: Macromiidae				
23	*Epophthalmia vittata*	5	0.57	SR
Suorder: Zogoptera				
Family: Coenagrionidae				
24	*Agriocnemis lacteola*	9	1.03	R
25	*A. pieris*	7	0.80	SR
26	*A. pygmaea*	32	3.66	SD
27	*Ceriagrion cerinorubellum*	9	1.03	R
28	*C. coromandelianum*	89	10.17	D
29	*C. olivaceum*	4	0.46	SR
30	*Ischnura aurora*	13	1.49	R
31	*I. rubilio*	3	0.34	SR
32	*I. senegalensis*	29	3.31	SD
33	*Mortonagrion aborense*	7	0.80	SR
34	*Pseudagrion decorum*	5	0.57	SR
35	*P. microcephalum*	8	0.91	SR
36	*P. rubriceps*	23	2.63	R
Family: Platycnemididae				
37	*Copera marginipes*	18	2.06	R
38	*C. vittata*	11	1.26	R

[Relative abundance (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].

or absence of certain groups or species indicates the quality of the habitat. In Haldia IB, *Orthetrum sabina* and *Brachythemis contaminata* being dominant may be considered as the most tolerant and best-adapted odonate species. As in the present study, Nayek & Roy (2016) also noticed *B. contaminata* to be the most dominant

Table 3. Dominance status of odonate species in Haldia Industrial Belt in Purba Medinipur District, West Bengal, India.

	Scientific name	No. of individuals	Relative abundance (%)	Dominance status
Suborder: Anisoptera				
Family: Aeshnidae				
1	*Anax guttatus*	3	0.70	SR
Family: Libellulidae				
2	*Brachydiplax chalybea*	4	0.93	SR
3	*B. sobrina*	11	2.57	R
4	*Brachythemis contaminata*	61	14.25	D
5	*Crocothemis servilia*	31	7.24	SD
6	*Diplocodes trivialis*	22	5.14	SD
7	*Neurothemis tullia*	15	3.50	SD
8	*Orthetrum sabina*	119	27.80	D
9	*Pantala flavescens*	24	5.61	SD
10	*Potamarcha congener*	27	6.31	SD
11	*Rhyothemis variegata*	5	1.17	R
12	*Urothemis signata*	9	2.10	R
Suborder: Zygoptera				
Family: Coenagrionidae				
13	*Aciagrion pallidum*	1	0.23	SR
14	*Agriocnemis kalinga*	3	0.70	SR
15	*A. pygmaea*	17	3.97	SD
16	*Ceriagrion cerinorubellum*	4	0.93	SR
17	*C. coromandelianum*	29	6.78	SD
18	*Ischnura mildredae*	2	0.47	SR
19	*I. senegalensis*	36	8.41	SD
20	*Onychargia atrocyana*	2	0.47	SR
Family: Platycnemididae				
21	*Copera ciliata*	3	0.70	SR

[Relative abundance (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].

species in Asansol-Durgapur industrial area. Species diversity and equitability indices were found to be higher in Tamluk as compared to those of Haldia IB (Table 4).

Since Shannon diversity index was more than three in Tamluk, this land use type might be considered as relatively stress-free and unpolluted following the criteria of Wilhm & Dorris (1968). Haldia IB, on the contrary, could be regarded as moderately polluted as Shannon index was less than three but more than one. Higher equitability value and lower dominance value are indicative, respectively, of homogeneity and relatively stress-free equitable environment. Dominance index increases with the increase in the harshness of the environment and decreases with equitability of the environment (Karr 1971). Ghosh & Bhattacharya (2018) also opined that a low dominance index is indicative of homogeneity in community structures and reflects a relatively stress-free environment. Since dominance index is lower and equitability index is higher in the Tamluk as compared to the Haldia IB, it may be suggested that the former represents a less polluted and relatively stress-free environment as compared to the latter. It may, therefore, be concluded that shifts in land use type can alter the community structure of odonates and that odonates have the potentiality to be used as an ecologic indicator of the health of an environment since pollution and perturbance decrease their density and diversity. Further in-depth experimental studies, however, are needed to prove this contention beyond any doubt.

Table 4. Species diversity, evenness, and dominance indices in the study area in Purba Medinipur District, West Bengal, India.

Indices	Tamluk	Haldia
Shannon index (H')	3.16	2.43
Equitability index (J)	0.87	0.80
Dominance index (D)	0.06	0.13

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Image 1. *Brachythemis contaminata* (male)

Image 2. *Crocothemis servilia* (female)

Image 3. *Pantala flavescens* (male)

Image 4. *Orthetrum sabina* (male)

Image 5. *Ceriagrion coromandelianum* (male)

Image 6. *Ischnura mildredae* (female)

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PLATINUM
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Foraging preferences of honey bees *Apis cerana* in Dakshina Kannada, Karnataka, India

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Abstract: Honey bees visit flowers for collecting nectar and pollen. Pollen serves as a source of protein for the survival of honeybees. To understand the dependence and preference of the honey bee species *Apis cerana* on different pollen resources, we carried out a study to analyze the distribution of different types of pollen in honey in various regions of the coastal plains of the Western Ghats. Fourteen different honey samples from different sites ranging in elevation from 55m to 135m were collected and analyzed. Acetolysis and centrifugation were used for pollen extraction from different honey samples. The extracted pollen was mixed with glycerin jelly and transferred to a glass slide for microscopic analysis. The primary source of pollen as revealed by the current study were found to be *Areca catechu, Cocos nucifera, Ixora coccinea, Mimosa pudica*, and *Psidium guajava.* Morphotype analysis revealed 12 different plants to be the source of the pollen. Each honey sample collected from different locations, however, had only three to six types of pollen indicating that honeybees visit a narrow or a small number of pollen sources. Therefore, based on our study, we conclude that lesser types of pollen in each honey sample indicates that their food resources are getting limited. Therefore, it is necessary to conserve pollen resources for the better survival of honey bees and the environment.

Keywords: *Areca catechu, Cocos nucifera,* coastal plains, *Ixora coccinea,* melissopalynological analysis, *Mimosa pudica*, nectar, pollen, *Psidium guajava*, Western Ghats.

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Author Contribution: AGSK has done all the experiments, AGSK & RKP have written the manuscript.

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INTRODUCTION

Among all insects that pollinate, honeybees are considered to be one of the crucial pollinators (Ballantyne et al. 2017). Animal pollination directly affects about three-quarters of essential crop types, including most fruits, seeds, and nuts (Smith et al. 2015). Honeybees collect different types of pollen and they are added or mixed with honey intentionally or accidentally. Melissopalynological analysis, or studies on pollen, are helpful in determining the geographical and botanical origin of honey (Louveaux et al. 1978; von der Ohe et al. 2004). These studies also evaluate the plant source required for honey production and such knowledge about the pollen resource helps improve beekeeping practices. A few melissopalynological studies were carried out in India, and our study aims to present the foraging preferences of honeybees in the coastal plains of the Western Ghats.

Vegetation of Dakshina Kannada that lies along the Western Ghats expresses itself with thousands of species and several hundred genera of plants. It harbours several endemic and rare plants; this range of diversity is because of the physiological and geographical positioning of Dakshina Kannada along the coastline, exposed to elevations ranging from sea level to about 4,500ft. It consists of the Western Ghats in the east and the seashore in the west. The soil is mostly lateritic and the topography of the district is plain up to 30km inside the coast and changes to undulating hilly terrain sharply towards the east in the Western Ghats (Dakshina Kannada District Profile 2015). Trees such as Bamboo, Rosewood *Dalbergia latifolia*, and Teak *Tectona grandis* are found in the hilly areas towards the east. In rural Dakshina Kannada, houses are situated between farmlands or plantations of Arecanut *Areca catechu* and Coconut *Cocos nucifera* (Anonymous 2015). The earliest research on the pollen present in honey was done by Pfister (1895) by carrying out an analysis of French, Swiss, and European honey. Deodikar et al. (1958) initiated palynological studies in Maharashtra in India. Later, others from different parts of India such as Andhra Pradesh (Ramanujam & Kalpana 1991; Lakshmi & Suryanarayana 2004; Ramakrishna & Swathi 2013; Devender & Ramakrishna 2015), Bihar (Suryanarayana et al. 1992), Himachal Pradesh (Sharma 1970; Sharma & Raj 1985), West Bengal (Bhattacharya et al. 1983; Chakraborti & Bhattacharya 2011; Kamble et al. 2015), Uttarakhand (Garg & Nair 1974), Karnataka (Chauhan & Murthy 2010; Shubharani et al. 2012; Raghunandan & Basavarajappa 2013), Orissa (Upadyay & Bera 2008, 2012, 2014), and Madhya Pradesh (Chauhan & Quamar 2010; Sahney & Seth 2013) conducted studies on these aspects.

MATERIALS AND METHODS

From February 2016 to April 2016, 14 honey samples were collected from 14 different locations of Dakshina Kannada District, which covers from 12.52^0N & 74.53^0E to 12.87^0N & 74.88^0E in the state of Karnataka, India, and has an area of 4,559km^2 (Dakshina Kannada District Profile 2015; Fig. 1). Beekeepers of different areas of Dakshina Kannada were approached and samples were collected from them with the intention of understanding the pollen preferences of honey bees in the district. The geographical position of the honey samples collected was also noted down and all 14 honey samples from different sites ranging in elevation of 55–135 m were sampled (Table 2).

The samples were stored in containers. Honey samples were collected from several apiaries of domesticated *Apis cerana indica* colonies. All honey samples were unprocessed and raw during the time of collection and they were extracted using honey extracting machines from honeycombs by beekeepers. The detailed information on the different honey samples collected is included in Table 1.

To do pollen analysis, 5g of honey sample was dissolved in 5ml of distilled water and centrifuged at 2,500rpm for 10min. After centrifugation, the sediment obtained was treated with 5ml glacial acetic acid. Later, the glacial acetic acid was removed and the material was subjected to acetolysis as per Erdtman (1952). This solution was again centrifuged and the supernatant solution was discarded; the sediment containing pollen was taken and added with glycerin jelly and was transferred to a glass slide. The glass slide was slightly heated to melt the jelly and cover slip was applied. To secure the coverslip, colourless nail polish was applied to its edges (Song et al. 2012; Ponnuchemy et al. 2014). To analyze the pollen present in the honey samples qualitatively and quantitatively, three pollen slides were prepared for each of the samples. Pollen types were identified by comparison with reference slides, which were prepared by collecting pollen directly from the plants in the study area. In addition, palynological literature were also used. For quantification of pollen types, 300 pollen grains were counted from each sample. The percentage frequency of the pollen taxa found in all the samples was calculated. The types of pollen were

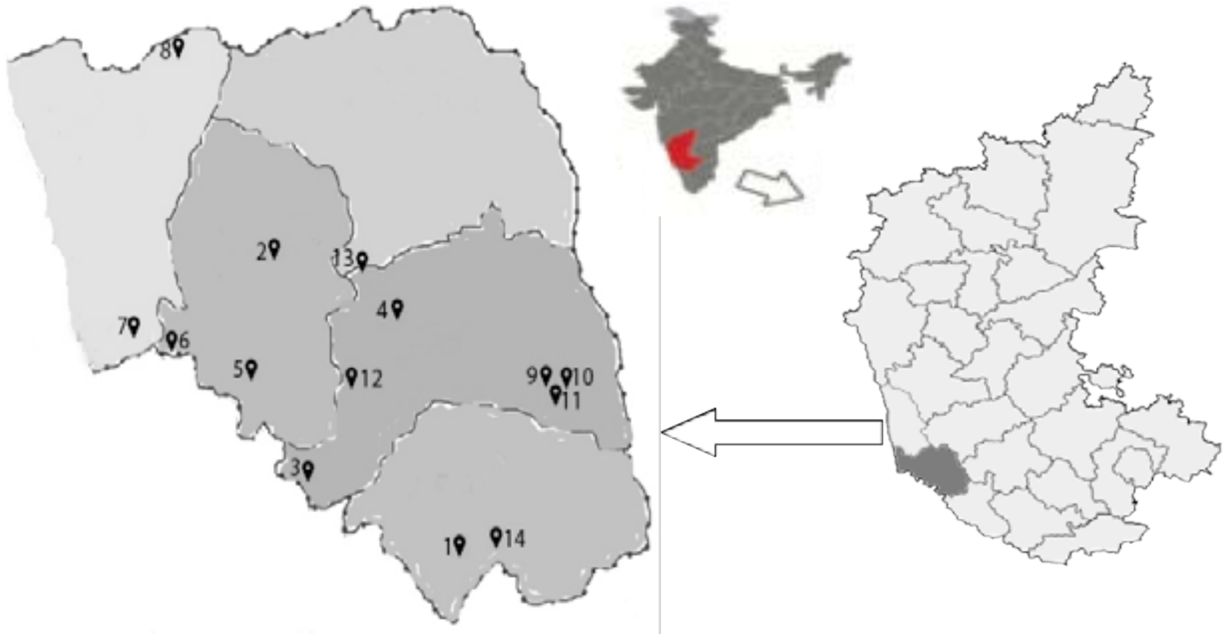

Figure 1. Dakshina Kannada District in Karnataka State, India, showing 14 sites of honey sample collection: 1 - Irde, 2 - Kelinja, 3 - Bettampady, 4 - Parladka, 5 - Mithanadka, 6 - Mudipu, 7 - Derlakatte, 8 - Belvai, 9 - Kadaba, 10 - Deppuni, 11 - Kundadka, 12 - Punacha, 13 - Uppinangady, 14 - Mitoor.

allocated to one of four frequency classes: i) predominant pollen type (>45%), ii) secondary pollen type (16–45%), iii) important minor pollen types (3–15 %), and iv) minor pollen types (<3%) (Louveaux et al. 1978; Song et al. 2012). Absolute pollen count in 1g of honey sample was also made. Pollen grains were observed using light microscopy; scanning electron microscopy was also used to observe predominant pollen types.

RESULTS

From the 14 honey samples, 12 pollen morphotypes were identified (Image 1). Eleven samples appeared to be unifloral with predominant pollen and three to be multi-floral. In the samples Irde (DK-Ir-01), Mithanadka (DK-Mi-05), and Mitoor (DK-Mt-14), *Ixora coccinea* was the predominant pollen with pollen ranging from 46% to 60%. In the samples Bettampady (DK-Be-03) and Kadaba (DK-Ka-09), *Cocos nucifera* was the predominant pollen ranging from 50% to 60%. In samples Mudipu (DK-Mu-06), Belvai (DK-Bl-08), Kundadka (DK-Ku-11), it was found that *Psidium guajava* pollen was predominant, ranging from 60% to 68%. In sample Deppuni (DK-Dp-10), *Areca catechu* was predominant with 48% pollen and in samples Derlakatte (DK-De-07) and Uppinangady (DK-Up-13), *Mimosa pudica* was predominant, ranging from 50% to 68% (Table 1). Some of the pollen such as *M. pudica*, *P. guajava*, *A. catechu*, *C. nucifera*, and *I. coccinea* were predominant (Image 2) and can be considered as important source of forage for honey bees in Dakshina Kannada.

Pollen of some species such as *Areca catechu* in samples DK-Ka-09 and DK-Be-03, *Cocos nucifera* in samples DK-Ir-01, DK-Pa-04, DK-Mi-05, DK-Mu-06, DK-Bl-08, DK-Dp-10, DK-Pu-12, DK-Up-13, and DK-Mt-14, *Ixora coccinae* in sample Dk-Pa-04, *Mimosa pudica* in samples DK-Ke-02 and DK-Ku-11, *Moringa olifera* in samples DK-Ir-01 and DK-Pa-04, *Psidium guajava* in samples DK-Pu-12 and DK-Ke-02, and *Syzigium* in sample DK-De-07 were found to be secondary pollen, whereas some others appeared to be minor pollen in specific samples, the details of which are given in Table 1. Geographical position of the honey samples collected from different sites is given in Table 2. Absolute pollen count was measured per gram of honey samples; minimum number of absolute pollen count was found in sample DK-De-07 with 1,740 pollen grains and maximum in sample DK-Mi-05 with 27,300 pollen grains. Percentage of pollen belonging to different plant species present in each of the honey samples were calculated. *Cocos nucifera* found in all honey samples was 30.142%, which was the maximum. The minimum percentage of pollen source was found to be *Acacia* sp., *Mangifera indica*, and *Eucalyptus* sp. (Table 3; Fig. 2). Twelve plant species identified as pollen sources belonged to

Table 1. Frequency class of pollen and data of pollen analysis performed with the honey samples collected from different locations in Dakshina Kannada District, Karnataka, India.

	Honey sample	Type of pollen			
		Predominant pollen (>45%)	Secondary pollen (16–45 %)	Important minor pollen (3–15 %)	Minor pollen (<3%)
1.	DK-Ir-01	*Ixora coccinea* (46%)	*Cocos nucifera* (30%), *Moringa olifera* (20%)	*Areca catechu* (3%)	*Mimosa pudica*
2.	DK-Ke-02	Nil	*Mimosa pudica* (42%), *Psidium guajava* (41%)	*Cocos nucifera* (15%)	Asteraceae
3.	DK-Be-03	*Cocos nucifera* (50%)	*Areca catechu* (45%)	*Psidiumguajava* (5%)	Nil
4.	DK-Pa-04	Nil	*Moringa olifera* (40%), *Ixora coccinea* (31%), *Cocos nucifera* (21%)	*Mimosa pudica* (7%)	*Mangifera indica*
5.	DK-Mi-05	*Ixora coccinea* (60%)	*Cocos nucifera* (30%)	*Mimosa pudica* (10%)	Nil
6.	DK-Mu-06	*Psidium guajava* (60%)	*Cocos nucifera* (26%)	*Areca catechu* (12%)	*Acacia* sp., *Eucalyptus sp.*
7.	DK-De-07	*Mimosa pudica* (50%)	*Syzygium* sp. (35%)	*Cocos nucifera* (15%)	Nil
8.	DK-Bl-08	*Psidium guajava* (68%)	*Cocos nucifera* (32%)	Nil	Nil
9.	DK-Ka-09	*Cocos nucifera* (60%)	*Areca catechu* (30%)	*Mimosa pudica* (9%)	Asteraceae
10.	DK-Dp-10	*Areca catechu* (48%)	*Cocos nucifera* (35%)	*Mimosa pudica* (15%)	*Psidium guajava*
11.	DK-Ku-11	*Psidium guajava* (60%)	*Mimosa pudica* (23%)	*Cocos nucifera* (7%), *Syzygium* sp. (6%)	*Areca catechu*, *Moringa olifera*
12.	DK-Pu-12	Nil	*Psidium guajava* (41%), *Cocos nucifera* (35%)	*Areca catechu* (10%), *Mimosa pudica* (10%)	Arecaceae, *Syzygium* sp.
13.	DK-Up-13	*Mimosa pudica* (68%)	*Cocos nucifera* (26%)	*Psidium guajava* (4%)	Arecaceae, *Moringa olifera*
14.	DK-Mt-14	*Ixora coccinea* (48%)	*Cocos nucifera* (40%)	*Moringa olifera* (10%)	*Mimosa pudica*

Irde (DK-Ir-01), Kelinja (DK-Ke-02), Bettampady (DK-Be-03), Parladka (DK-Pa-04), Mithanadka (DK-Mi-05), Mudipu (DK-Mu-06), Derlakatte (DK-De-07), Belvai (DK-Bl-08), Kadaba (DK-Ka-09), Deppuni (DK-Dp-10), Kundadka (DK-Ku-11), Punacha (DK-Pu-12), Uppinangady (DK-Up-13), Mitoor (DK-Mt-14).

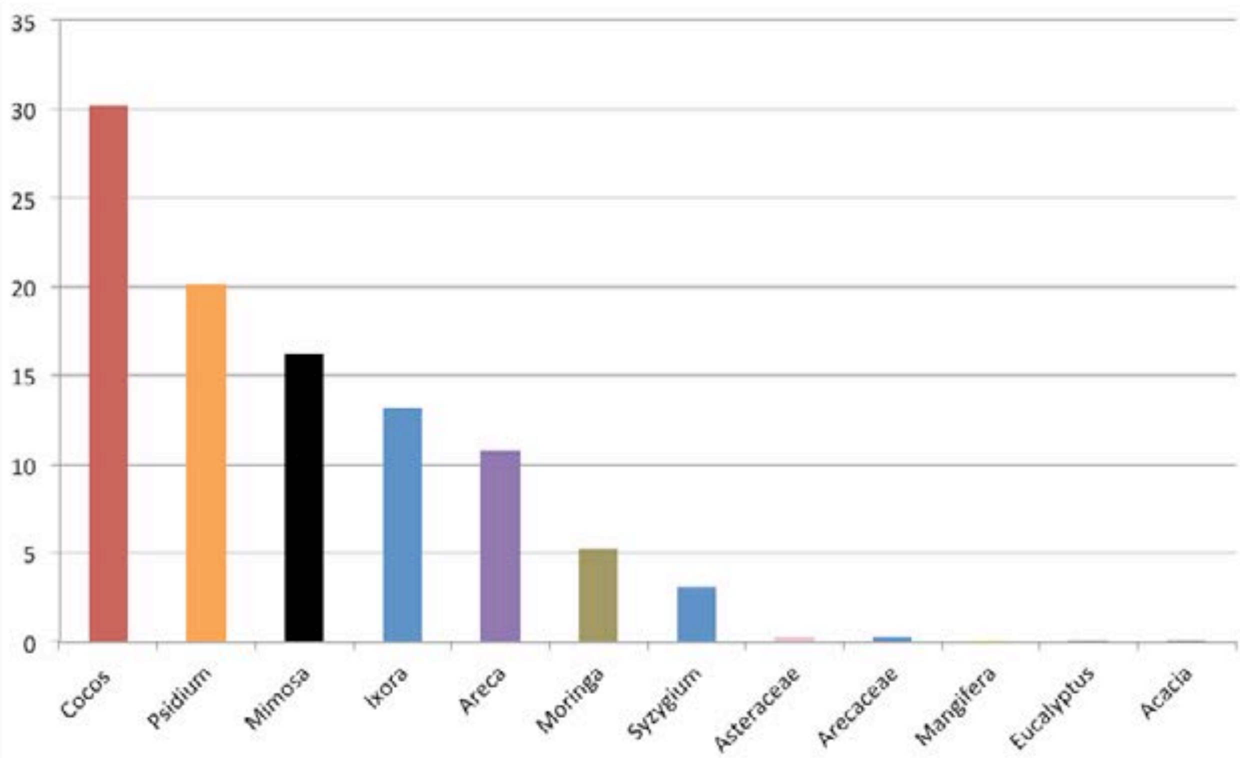

Figure 2. Total percentage of pollen sources found in all 14 sites of Dakshina Kannada District, Karnataka, India.

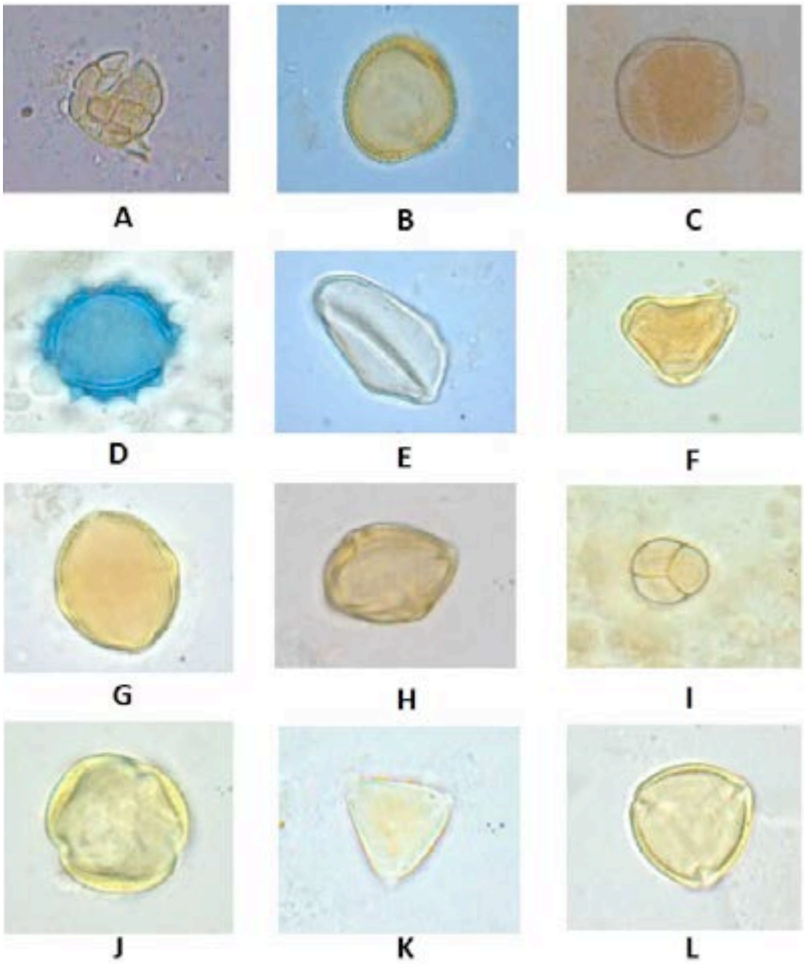

Image 1. Microscopic images of pollen grains found in honey samples: a - *Acacia* | b - *Areca catechu* | c - Arecaceae | d - Asteraceae | e - *Cocos nucifera* | f - *Eucalyptus* sp. | g - *Ixora coccinea* | h - *Mangifera indica* | i - *Mimosa pudica* | j - *Moringa olifera* | k - *Psidium guajava* | l - *Syzygium* sp.

seven families. Three species belonged to Arecaceae, three to Myrtaceae, and two to Fabaceae; Rubiaceae, Anacardiaceae, Asteraceae, and Moringaceae had one species each (Table 4). Pollen count of each of the pollen sources found in all the samples was also made (Table 5). *Cocos nucifera* was found in honey samples collected from all 14 sites and therefore can be considered as one of the most important pollen sources in Dakshina Kannada.

DISCUSSION

The protein that pollen provides is essential for brood production and development of young honey bees. Pollen is also the primary source of protein to honey bees. Stored pollen grains along with glandular secretions containing enzymes and acids is called bee bread. Larval honey bees feed on bee bread and brood food mixture. Enzymes and acids are added to the pollen by the bees so that it can be preserved for long term (Ellis et al. 2010). In order to complete the development of the body, newly emerged bees also feed on bee bread. The requirement of bee bread by a single worker bee larva is estimated to be about 124–145 mg; this consists of about 30mg of protein. A diet of high protein pollen increases the longevity of worker bees and also improves brood rearing; brood rearing gets reduced when supported by pollen grains low in protein. It is observed that honey bees choose pollen based on the physical configuration and odour of the pollen rather than based on their nutritive value. On average, 15–30 % of the colony's forager bees collect pollen, and a single bee can carry and bring back pollen load that weighs about 35% of the bee's body weight. Bees carry pollen on their hind legs, on specialized structures commonly

Table 2. Geographical position of samples collected and absolute pollen count of the honey samples from Dakshina Kannada District, Karnataka, India.

	Honey sample	Geographical position	Elevation (m)	Absolute pollen count (APC)
1.	DK-Ir-01	12.672^{0}N, 75.200^{0}E	84.5	1780
2.	DK-Ke-02	12.802^{0}N, 75.087^{0}E	84.6	2520
3.	DK-Be-03	12.662^{0}N, 75.199^{0}E	112.2	16260
4.	DK-Pa-04	12.749^{0}N, 75.204^{0}E	110.6	4800
5.	DK-Mi-05	12.732^{0}N, 75.022^{0}E	91.1	27300
6.	DK-Mu-06	12.795^{0}N, 74.970^{0}E	122.8	3660
7.	DK-De-07	12.809^{0}N, 74.883^{0}E	55.5	1740
8.	DK-Bl-08	13.125^{0}N, 74.997^{0}E	126.2	2640
9.	DK-Ka-09	12.731^{0}N, 75.471^{0}E	107.2	1900
10.	DK-Dp-10	12.722^{0}N, 75.499^{0}E	130.6	2960
11.	DK-Ku-11	12.711^{0}N, 75.470^{0}E	104.0	3720
12.	DK-Pu-12	12.723^{0}N, 75.148^{0}E	103.7	1920
13.	DK-Up-13	12.838^{0}N, 75.255^{0}E	40.8	15840
14.	DK-Mt-14	12.556^{0}N, 75.428^{0}E	135.3	1790

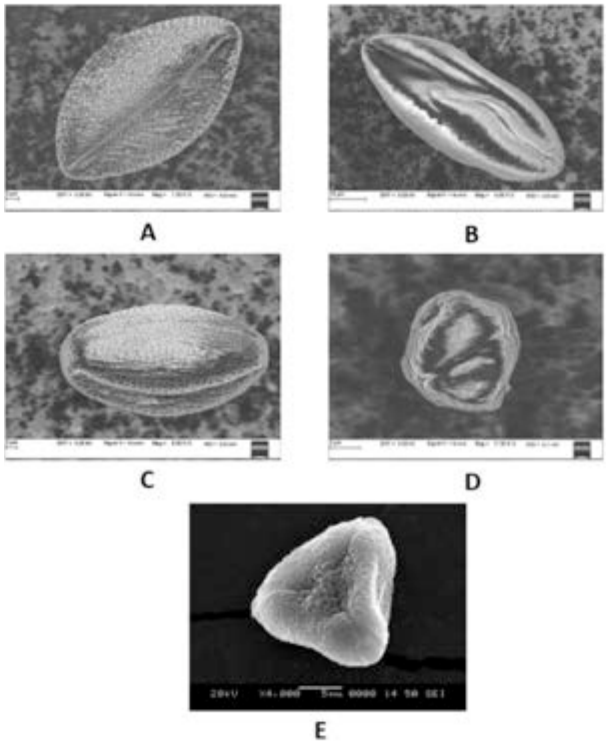

Image 2. Scanning electron microscope images of predominant pollen grains observed: a - *Areca catechu* | b - *Cocos nucifera* | c - *Ixora coccinea* | d - *Mimosa pudica* | e - *Psidium guajava*.

called pollen baskets, also known as corbicula (Ellis et al. 2010).

It is assumed that pollen found in honey sediment falls into the nectar while in the flower, which is then transported in the bee's honey stomach to the hive. This pollen will be present during the ripening process, and also appear finally in ripe honey (Maurizio 1951).

Our study reveals the variation in the amount and type of pollen present in the samples. Several uncontrollable factors influence the presence of pollen types in honey samples; some of them are the availability of pollen, unbalance in the abundance of flowers among plant species, and the honey bee's collection preferences. In fact, there is a necessity of more studies addressing these questions more specifically with controlled experiments (Oliveira et al. 2010). The presence of pollen types in honey samples indicates the botanical origin of the honey to that region. Battesti & Goevry (1992) verified that climatic conditions influence the metalliferous and polleniferous potential of the local flora. Pollen richness in the honey sample depends on the pollen production by the parent plant, climatic conditions, the distance from the beehive to the flower field, filtering of pollen by the bees' proventriculus, the diameter of the pollen grain, and method of extraction of honey (von der Ohe 1994). Significant variation in pollen content is caused due to some factors like i) the amount of pollen filtered out in the bee's honey sac (Maurizio 1975) and ii) the bee taking only pollen without the nectar (Anklam 1998). Chaturvadi (1983) verified that the pollen spectra of honey are also influenced by the crops which are cultivated in the localities. The pollen types and percentage of pollen in honey does not represent genuinely the same proportion of quantity of nectar gathered from these plants because some pollen types are over-represented and some underrepresented; however, from the pollen spectra, it is apparent that honey bees eagerly visit the honey sources for nectar and pollen to form honey (Maurizio 1975). When the bees collect and transfer nectar to their honey stomach, the amount of pollen in the nectar get reduced. The honey stomach is connected to the ventriculus by the proventriculus; the valves of the proventriculus remain closed during foraging and opens only when the bee feeds for itself. This valve in its closed position can abstract small solid particles from the full honey stomach and pass them into the ventriculus. While doing so, the volume of the fluid does not get reduced (Whitcomb &

Table 3. Plant species and the percentage of pollen found in honey samples obtained from different sites in Dakshina Kannada District, Karnataka, India.

	Plant species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Total %
1.	*Acacia* sp.	-	-	-	-	-	1%	-	-	-	-	-	-	-	-	0.071
2.	*Areca catechu*	3%	-	45%	-	-	12%	-	-	30%	48%	2%	10%	-	-	10.714
3.	Arecaceae	-	-	-	-	-	-	-	-	-	-	-	2%	1%	-	0.214
4.	Asteraceae	-	2%	-	-	-	-	-	-	1%	-	-	-	-	-	0.214
5.	*Cocos nucifera*	30%	15%	50%	21%	30%	26%	15%	32%	60%	35%	7%	35%	26%	40%	30.142
6.	*Eucalyptus* sp.	-	-	-	-	-	1%	-	-	-	-	-	-	-	-	0.071
7.	*Ixora coccinea*	46%	-	-	31%	60%	-	-	-	-	-	-	-	-	48%	13.214
8.	*Mangifera indica*	-	-	-	1%	-	-	-	-	-	-	-	-	-	-	0.071
9.	*Mimosa pudica*	1%	42%	-	7%	-	-	50%	-	9%	15%	23%	10%	68%	2%	16.214
10.	*Moringa olifera*	20%	-	-	40%	-	-	-	-	-	-	2%	-	1%	10%	5.214
11.	*Psidium guajava*	-	41%	5%	-	-	60%	-	68%	-	2%	60%	41%	4%	-	20.071
12.	*Syzygium* sp.	-	-	-	-	-	-	35%	-	-	-	6%	2%	-	-	3.071

Table 4. Plant species as pollen sources, their families, habit, and number of sites in which they are found in Dakshina Kannada District, Karnataka, India.

	Plant species	Family	Habit	Number of sites
1	*Acacia*	Fabaceae	Tree	1
2	*Areca catechu*	Arecaceae	Tree	7
3	Arecaceae	Arecaceae	Tree	2
4	Asteraceae	Asteraceae	Creeper	2
5	*Cocos nucifera*	Arecaceae	Tree	14
6	*Eucalyptus* sp.	Myrtaceae	Tree	1
7	*Ixora coccinea*	Rubiaceae	Shrub	4
8	*Mangifera indica*	Anacardiaceae	Tree	1
9	*Mimosa pudica*	Fabaceae	Herb	11
10	*Moringa olifera*	Moringaceae	Tree	5
11	*Psidium guajava*	Myrtaceae	Tree	8
12	*Syzygium* sp.	Myrtaceae	Tree	3

Wilson 1929; Todd & Vansell 1942). For example, if the bees feed on syrup containing pollen, the pollen content of the honey stomach is reduced to one-half or one-third in the first 15–30 min after feeding. Therefore, it must be reckoned that the amount of pollen in the honey is dependent on the time taken by the bee to return from the source of forage to the hive. So a question arises whether a selection process of pollen grains according to their size takes place during the transfer of pollen through the proventriculus, which would alter the relative proportions of different pollen grains (Whitcomb & Wilson 1929; Todd & Vansell 1942). An experiment conducted by Maurizio (1949), however, verified that neither the size of the pollen nor the concentration of the syrup nor the original pollen content of the syrup significantly affected the rate of pollen disappearing from the honey stomach. Therefore, the amount of pollen is indeed reduced but no selection process is known that would alter the proportions of different types of pollen present in the syrup.

From the above observations, it is clear that all these species contribute as pollen sources for honey bees and some of the predominant pollen sources are very important for the endurance and survival of honey bee colonies and also for the development of apiculture industry in the study area. For the survival of honey bee colonies and the improvement of apiculture, knowledge of honey plants and pollen sources is of utmost importance. The study of honey bees that are excellent pollinators also contribute to the increased pollination and production of food crops, economically important plants, and medicinal plants, which in turn improve the economy of forest and rural areas. In horticulture, bee pollination leads to higher number of fruits, berries, or seeds. It also gives better quality products. Some crops have flowers that are pollinated during a short period. If such crops are not pollinated during the limited time interval, flowers will fall and no seeds, fruits, or berries will develop. There should be a sufficient number of bees in order to pollinate crops. Based on all the above observations, conservation of honey plants are crucial and much necessary. Depletion of honey plants will directly affect the number of honey bee colonies, causing their respective decline, which

Table 5. Pollen sources and their pollen count in different sites in Dakshina Kannada District, Karnataka, India.

Site	*Acacia*	*Areca*	Arecacea	Asteracea	*Cocos*	*Eucalyptus*	*Ixora*	*Mangifera*	*Mimosa*	*Moringa*	*Psidium*	*Syzygium*
1	-	53	-	-	534	-	818	-	17	356	-	-
2	-	-	-	50	378	-	-	-	1,058	-	1,033	-
3	-	7,317	-	-	8,130	-	-	-	-	-	813	-
4	-	-	-	-	1,008	-	1,488	48	336	1,920	-	-
5	-	-	-	-	8,190	-	16,380	-	2,730	-	-	-
6	36	432	-	-	936	36	-	-	-	-	2160	-
7	-	-	-	-	261	-	-	-	870	-	-	609
8	-	-	-	-	844	-	-	-	-	-	1795	-
9	-	570	-	-	1,140	-	19	-	171	-	-	-
10	-	1,420	-	-	1,036	-	-	-	444	-	59	-
11	-	74	-	-	260	-	-	-	855	74	2,232	223
12	-	192	38	-	672	-	-	-	192	-	787	38
13	-	-	158	-	4118	-	-	-	10771	158	633	-
14	-	716	859	35	-	-	179	-	-	-	-	-

1 - Irde, 2 - Kelinja, 3 - Bettampady, 4 - Parladka, 5 - Mithanadka, 6 - Mudipu, 7 - Derlakatte, 8 - Belvai, 9 - Kadaba, 10 - Deppuni, 11 - Kundadka, 12 - Punacha, 13 - Uppinangady, 14 - Mitoor.

will lead to the downfall of agriculture and economy of the area. Artificial pollination is unimaginable and is practically very difficult. Therefore, honey plants which are essential pollen sources must be protected and conserved well.

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ADDITIONS TO THE LICHEN BIOTA OF ASSAM STATE, INDIA

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Abstract: The present paper deals with 25 new records of lichens under 19 genera and 11 families for the state of Assam in India. The newly reported species from Assam are *Alyxoria apomelaena*, *A. culmigena*, *A. varia*, *Caloplaca pseudisteroides*, *Cryptothecia striata*, *Diorygma rupicola*, *Dirinaria papillulifera*, *Flavoplaca citrina*, *Graphis sundarbanensis*, *Herpothallon echinatum*, *Lecanographa rufa*, *Letrouitia muralis*, *Myriotrema clandestinum*, *Opegrapha discolor*, *Parmotrema crinitoides*, *Phaeophyscia hispidula*, *Porina eminentior*, *P. interstes*, *P. mastoidella*, *Pyrenula submastophora*, *P. thelomorpha*, *Rinodina oxydata*, *Synarthonia bicolor*, *Zwackhia bonplandii*, and *Z. viridis*. Brief descriptions of these additional lichen taxa from Assam are provided to facilitate their identification.

Keywords: Lichenized fungi, Nagaon District, new records, taxonomy.

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Author contribution: RG contributed in collection, herbarium preparation, characterization, identification of the specimens and writing the manuscript. FY contributed in collection and identification of specimens and preparation of manuscript. SJ contributed in identification of the specimens and writing the manuscript. SN conceived the study, its design and contributed in identification of specimens and improvement of the manuscript.

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INTRODUCTION

Assam is rich in floral as well as faunal diversity and comes under the northeastern Indian biogeographic zone. The extraordinary physiography makes the region suitable to colonize diverse organisms including lichenized fungi. Despite being rich in biodiversity, the exploratory work on lichens of Assam is scanty. Floristic study on lichens in Assam was pioneered by Stirton (1881), a Scottish lichenologist who described 39 lichen species only from tea plants. To augment the floristic study in Assam, a few researchers made their contributions to the lichen biota of the state (Awasthi & Singh 1973; Pant & Upreti 1993; Rout et al. 2005, 2010; Gupta & Sinha 2011, 2016; Sinha et al. 2013; Daimari et al. 2014). Recently, Gupta & Sinha (2018) reported 300 species of lichen belonging to 83 genera and 26 families from Assam. The present study is an attempt to explore lichens from different localities of Nagaon District of Assam. The study resulted in 25 new records under 19 genera and 11 families to the state.

MATERIALS AND METHODS

The lichen specimens were collected from 05 February 2017 to 21 March 2018. Collected lichen specimens were dried and preserved in herbarium packets and deposited in the herbarium of CSIR-National Botanical Research Institute, Lucknow (LWG). The morphological characterization of lichen thallus was done under a Leica EZ4 stereo zoom microscope. Thin hand-cut sections of ascoma and thallus were mounted in distilled water, lactophenol cotton blue (LCB), 5% KOH, and Lugol's iodine solution and observed under a Leica DM2500 compound microscope. Chemical spot tests on the thallus and ascomatal tissue were done following Orange et al. (2001) by using the usual reagents K (5% aqueous solution of potassium hydroxide), C (aqueous solution of calcium hypochlorite), and P (0.5g of para-phenylenediamine dissolved in 5ml of ethanol). Thin layer chromatography was performed in solvent system C (toluene:acetic acid; 85:15 ml) following Orange et al. (2001). Identification of taxa was done by relevant published literature (Awasthi 1991, 2007; Upreti 1994; McCarthy 2003; Joshi et al. 2008, 2012; Ertz 2009; Lücking et al. 2009, 2016a; Aptroot 2012; Sharma & Khadikar 2012; Bungartz et al. 2013; Ram 2014; Joseph & Sinha 2015; Joseph et al. 2016, 2018). The nomenclature and classification of lichens were updated following Lücking et al. (2016b).

RESULTS

The study resulted in the addition of 25 species to the lichen flora of Assam. These species belong to 11 families and 19 genera. A brief taxonomic account of the new records is given below.

1. *Alyxoria apomelaena* (A. Massal.) Ertz, *Phytotaxa* 217 (1): 4. 2015. *Opegrapha apomelaena* A. Massal. in Krempelhuber, *Verh. K.K. Zool.-Bot. Ges. Wien* 21: 864. 1871. (Lecanographaceae) (Image 1a,b,c).

Specimen examined: LWG 35850, 21.iv.2018, Assam, Nagaon District, Kaliabor, Hatimura, 26.613°N, 92.993°E, 133m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, thin to inconspicuous, pale yellow, border line dark brown. Ascomata lirellate, rarely branched, straight to slightly curved, disc slit to exposed, epruinose; excipulum broadly continuous below the hypothecium, 25–40 µm thickened laterally; epihymenium slightly brownish 10–20 µm thick, I+ red; hymenium hyaline, inspersed with minute oil globules, 40–60 µm thick; paraphysoids branched and anastomosing; hypothecium I+ red. Asci clavate, 8-spored, 40–50 µm × 10–15 µm; ascospores hyaline, transversely 7–12-septate, 24.8–35.4 µm × 3.5–3.9 µm, perispore 1–2 µm thick.

Chemistry: Thallus K-, C-, P-, UV-; no lichen substance detected in TLC.

Distribution: India (Assam and Andaman & Nicobar Islands), Africa, Australia, Bolivia, Brazil, Chagos Archipelago, Colombia, French Guiana, Indonesia, Panama, Papua New Guinea, Peru, Solomon Islands, Thailand, The Seychelles, and Venezuela.

2. *Alyxoria culmigena* (Lib.) Ertz, *Bull. Soc. Naturalistes Luxemb*. 113:105. 2012. *Opegrapha culmigena* Lib., *Pl. Crypt. Arduenna*, Fasc. (Liège) 1: no. 15. 1830. (Lecanographaceae) (Image 2a,b,c).

Specimen examined: LWG 35851, 19.i.2017, Assam, Nagaon District, Doboka Reserve Forest, Kondoli Hill, 26.192°N, 92.781°E, 136m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, thin to inconspicuous, surface smooth, yellowish. Ascomata lirellate, emerged, straight, curved to flexuous, disc slit to exposed, black, epruinose; excipulum broadly continuous below the hypothecium, K+ slightly olivaceous; hypothecium I+ red, KI+ blue; hymenium hyaline, not inspersed; paraphysoids branched and anastomosing. Asci 8-spored; ascospores hyaline, transversely 3-septate, 18–18.5 µm × 2.5–2.9 µm, perispore ca. 1µm thick.

Image 1a. *Alyxoria apomelaena* (A. Massal.) Ertz. © Rupjyoti Gogoi.

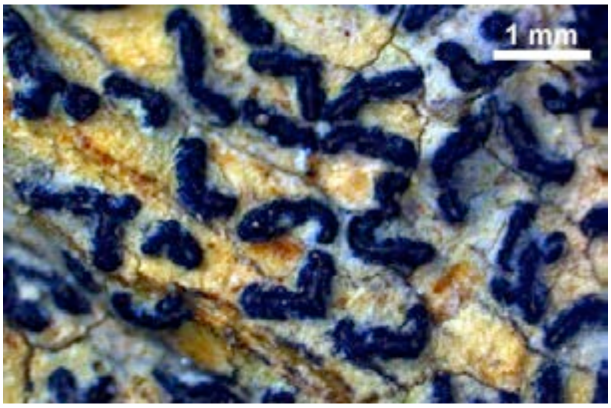

Image 2a. *Alyxoria culmigena* (Lib.) Ertz. © Rupjyoti Gogoi.

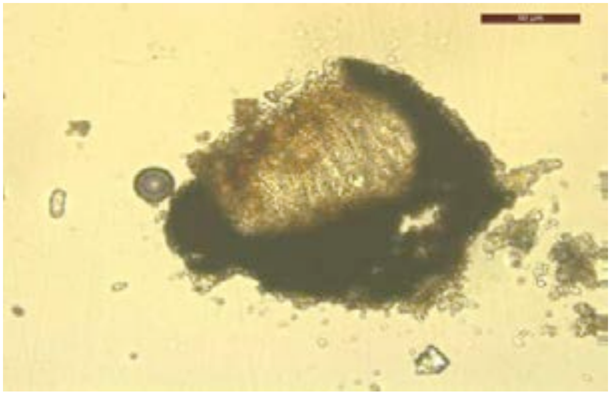

Image 1b. Longitudinal section of ascoma of *Alyxoria apomelaena* (A. Massal.) Ertz. © Rupjyoti Gogoi.

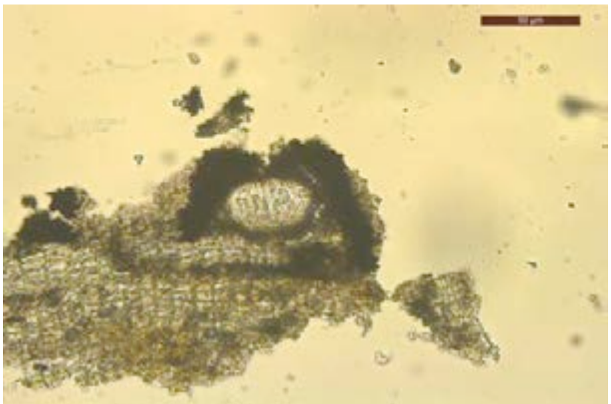

Image 2b. Longitudinal section of ascoma *Alyxoria culmigena* (Lib.) Ertz. © Rupjyoti Gogoi.

Image 1c. Ascospore of *Alyxoria apomelaena* (A. Massal.) Ertz. © Rupjyoti Gogoi.

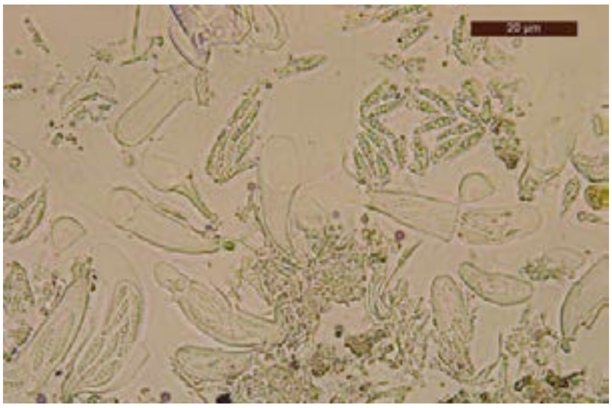

Image 2c. Ascospores of *Alyxoria culmigena* (Lib.) Ertz. © Rupjyoti Gogoi.

Chemistry: Thallus K-, C-, P-, UV-; no lichen substance detected in TLC.

Distribution: India (Andaman & Nicobar Islands and Assam), Africa, France, Galapagos Islands, Great Britain, Ireland, Malaysia, Papua New Guinea, Republic of Korea, Tasmania, and Thailand.

3. *Alyxoria varia* (Pers.) Ertz & Tehler, *Fungal Diversity* 49(1): 53. 2011. *Opegrapha varia* Pers., *Ann. Bot.* (Usteri) 1(7): 30. 1794. (Lecanographaceae) (Image 3a,b, c).

Specimens examined: LWG 35852, 31.x.2017, Assam, Nagaon District, Kampur, Kampur-Kathiatoli Road,

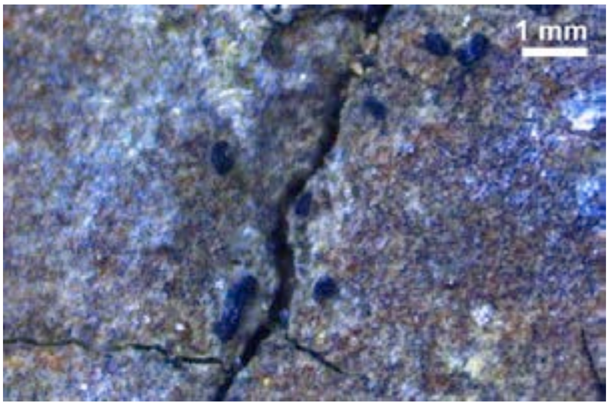

Image 3a. *Alyxoria varia* (Pers.) Ertz & Tehler. © Rupjyoti Gogoi.

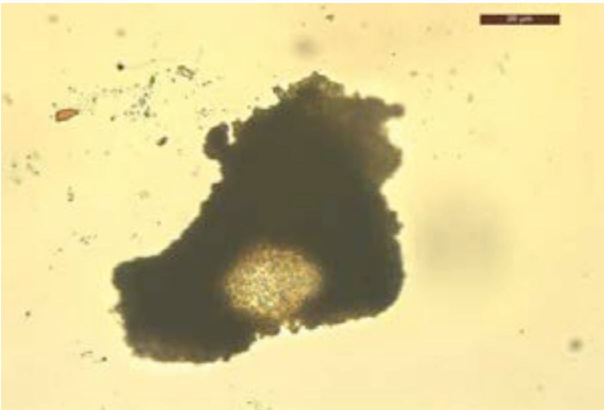
Image 3b. Longitudinal section of ascoma of *Alyxoria varia* (Pers.) Ertz & Tehler. © Rupjyoti Gogoi.

Image 3c. Ascospores of *Alyxoria varia* (Pers.) Ertz & Tehler. © Rupjyoti Gogoi.

26.173°N, 72.700°E, 81m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, inconspicuous, surface smooth, pale yellowish. Ascomata lirellate, short, unbranched, straight to flexuous, disc slit like to widely open, closed at base, epruinose; excipulum broadly continuous below the hypothecium, I+ red; hymenium hyaline, not inspersed, I+ red. Ascus 8-spored, clavate; ascospores hyaline, transversely 3–4-septate, 13.9–21.36 µm × 4.9–6.4 µm, perispore ca. 1µm thick.

Chemistry: Thallus K-, C-, P-, UV-; no lichen substance detected in TLC.

Distribution: India (Arunachal Pradesh, Assam, Goa, Karnataka, Maharashtra, Tamil Nadu, Uttar Pradesh, and West Bengal plains), Africa, Australia, Belarus, Fiji, France, Galapagos Islands, Greece, Hong Kong, Indonesia, Italy, Japan, La Réunion, Montenegro, North America, Papua New Guinea, Singapore, Sri Lanka, Taiwan, and The Philippines.

4. *Caloplaca pseudisteroides* Y. Joshi & Upreti, *Lichenologist* 40(6): 537. 2008. (Teloschistaceae) (Image 4a,b,c).

Specimen examined: LWG 35853, 19.i.2017, Assam, Nagaon District, Doboka Reserve Forest, 26.201°N, 92.795°E, 90m, coll. Rupjyoti Gogoi.

Description: Thallus saxicolous, crustose, cracked, areolate to subsquamulose, olivaceous grey, hypothallus black. Ascomata apothecia, numerous, scattered, immersed to sessile, restricted to the centre of the thallus, disc brownish-black, thalline margin smooth, concolorous with the thallus; epihymenium golden brown to brown; hymenium hyaline. Asci 8-spored; ascospores polaribilocular, broadly ellipsoidal, 7.6–11.29 µm × 4–5.2 µm.

Chemistry: Thallus K+ pale yellow, C-, P-, UV-; atranorin detected in TLC.

Distribution: India (Assam and Madhya Pradesh).

5. *Cryptothecia striata* G. Thor, *Bryologist* 31: 278. 1991. (Arthoniaceae) (Image 5a,b).

Specimen examined: LWG 35854, 17.iii.2018, Assam, Nagaon District, Jugijan, Na-Nath Archaeological Site, 26.033°N, 92.774°E, 71m, coll. Rupjyoti Gogoi.

Description: Thallus saxicolous, crustose, greyish-white, cottony, ecorticate, delimited by a distinct byssoid prothallus of white, radiating hyphae, medulla white. Ascigerous areas in the centre of the thallus, merged into distinct radiating striae. Asci bitunicate, pyriform to globose with a short stalk, ascus 1-spored; ascospores hyaline, ovoid to oblong, muriform, slightly curved, 31.7–40 µm × 12.5–15 µm.

Chemistry: Thallus K-, C+ bright red, P-, UV-; gyrophoric acid detected in TLC.

Distribution: India (Andaman & Nicobar Islands and Assam) and Florida.

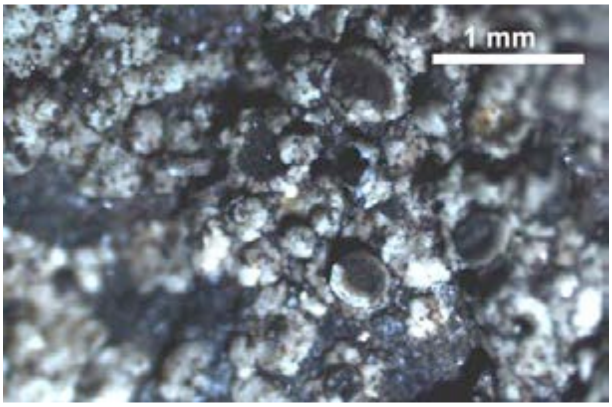

Image 4a. *Caloplaca pseudisteroides* Y. Joshi & Upreti. © Rupjyoti Gogoi.

Image 5a. *Cryptothecia striata* G. Thor. © Rupjyoti Gogoi.

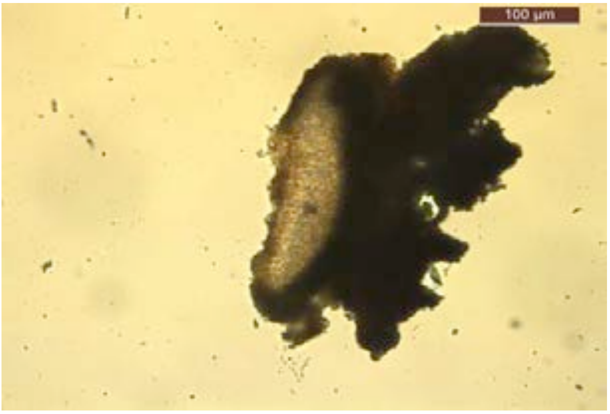

Image 4b. Longitudinal section of ascoma of *Caloplaca pseudisteroides* Y. Joshi & Upreti. © Rupjyoti Gogoi.

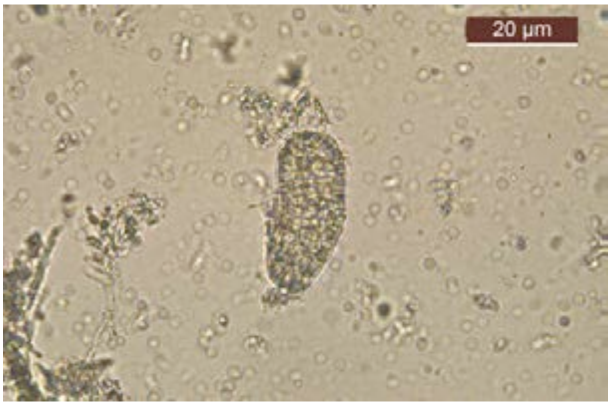

Image 5b. Ascospore of *Cryptothecia striata* G. Thor. © Rupjyoti Gogoi.

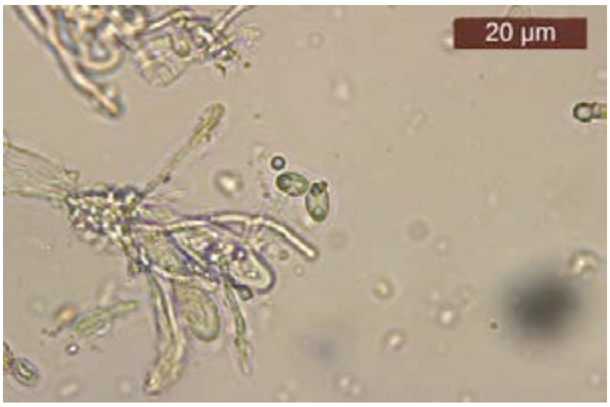

Image 4c. Ascospores of *Caloplaca pseudisteroides* Y. Joshi & Upreti. © Rupjyoti Gogoi.

6. *Diorygma rupicola* B.O. Sharma & Khadikar, *Mycotaxon*. 119: 5. 2012. (Graphidaceae) (Image 6a,b,c).

Specimen examined: LWG 35855, 18.ii.2018, Assam, Ngaon District, Samaguri, Suang Reserve Forest, 26.313°N, 92.880°E, 85m, coll. Rupjyoti Gogoi.

Description: Thallus saxicolous, crustose, greyish-white. Ascomata concolorous with the thallus, lirellate, simple, immersed, short, stellate, disc narrow, pruinose, rarely open; excipulum convergent, apically carbonized; hymenium hyaline, not inspersed. Asci 1-spored; ascospores hyaline, muriform, I+ blue, 75.5–94.6 µm × 14.3–24.6 µm.

Chemistry: Thallus K+ yellow, C-, P-; norstictic acid, stictic acid and constictic acid detected in TLC.

Distribution: India (Assam, Meghalaya, Nagaland, and Sikkim).

7. *Dirinaria papillulifera* (Nyl.) D.D. Awasthi, *Bryologist* 67: 369. 1964. *Physcia papillifera* Nyl., *Expos. Synopt. Pyrenocarp.*: 42. 1858. *Physcia papillulifera* Nyl. *Acta Soc. Sci. Fenn.* 26(10): 9. 1900. (Caliciaceae) (Image 7).

Specimen examined: LWG 35856, 10.xii.2017, Assam, Ngaon District, Jugijan, Na-Nath Archaeological Site, 26.033°N, 92.774°E, 71m, coll. Rupjyoti Gogoi.

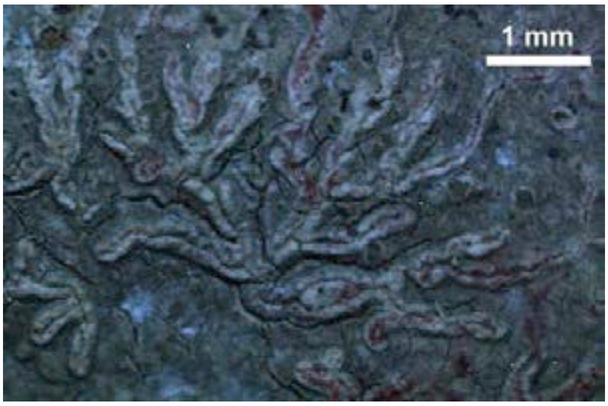

Image 6a. *Diorygma rupicola* B.O. Sharma & Khadikar. © Rupjyoti Gogoi.

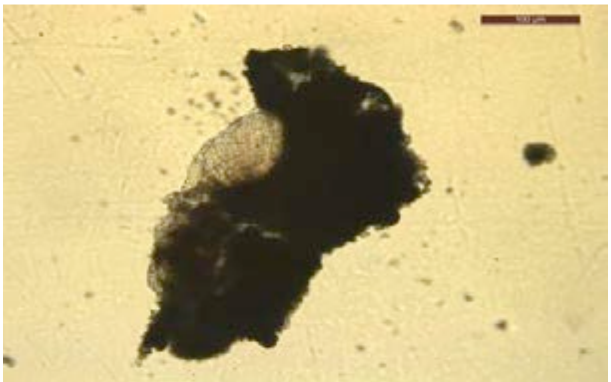

Image 6b. Longitudinal section of ascoma of *Diorygma rupicola* B.O. Sharma & Khadikar. © Rupjyoti Gogoi.

Image 6c. Ascospore of *Diorygma rupicola* B.O. Sharma & Khadikar. © Rupjyoti Gogoi.

Description: Thallus saxicolous, foliose, closely attached, 4.5mm across, lobe 1.8mm across, upper side grey-white, medulla white, isidia filiform. Apothecia not seen.

Chemistry: Thallus K+ yellow (cortex), C-, P-; divaricatic acid detected in TLC.

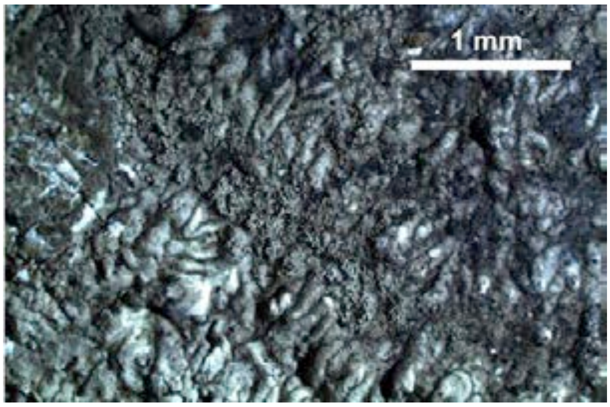

Image 7. *Dirinaria papillulifera* (Nyl.) D.D. Awasthi. © Rupjyoti Gogoi.

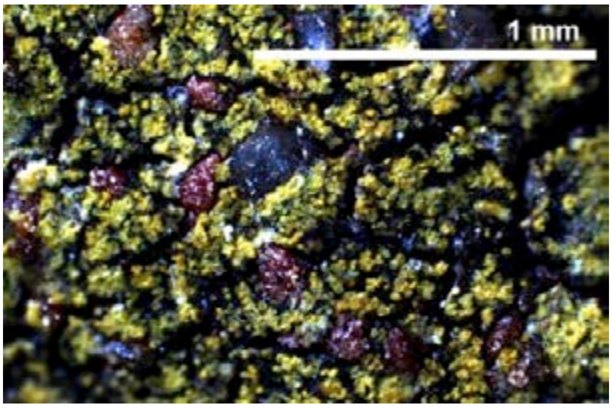

Image 8. Flavoplaca citrina (Hoffm.) Arup. © Rupjyoti Gogoi.

Distribution: India (Andaman & Nicobar Islands, Assam, Orissa, Tamil Nadu, Uttar Pradesh, and West Bengal plains), Brazil, Indonesia, Jamaica, Nicaragua, Panama, Sri Lanka, and Thailand.

8. *Flavoplaca citrina* (Hoffm.) Arup, Frödén & Søchting, *Nordic J. Bot.*31(1): 44. 2013. *Verrucaria citrina* Hoffm., *Deutschl. Fl.*: 198. 1796. *Caloplaca citrina* (Hoffm.) Th. Fr., *Nova Acta Regiae Soc. Sci. Upsal.*, ser. 3, 3: 218. 1861. (Telochistaceae) (Image 8).

Specimen examined: LWG 35857, 17.iii.2018, Assam, Nagaon District, Jugijan, Na-Nath Archaeological Site, 26.033°N, 92.774°E, 70m, coll. Rupjyoti Gogoi.

Description: Thallus saxicolous, crustose, areoles flat to convex, yellow, sorediate, soralia concolorous with the thallus, sometimes completely covering the thallus. Apothecia not seen.

Chemistry: Thallus K+ purple, C-, P-, UV-.

Distribution: India (Assam, Jammu & Kashmir, Madhya Pradesh, Maharashtra, and Tamil Nadu), Brazil, Hawaii, Israel, New Zealand, Ukraine, Africa, and North

America. Cosmopolitan.

9. *Graphis sundarbanensis* Jagadeesh & G.P. Sinha, *Lichenologist* 39(3): 231. 2007. (Graphidaceae) (Image 9a,b,c).

Specimen examined: LWG 35858, 10.xii.2017, Assam, Nagaon District, Jamunamukh, Erakapili, 26.098°N, 92.745°E, 68m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, greenish-grey. Ascomata lirellate, lirellae long, radiately branched, labia entire, pruinose, disc exposed; excipulum laterally carbonized; hymenium clear. Asci 8-spored, ascospores hyaline, transversely 6–8-septate, 11.8–16.1 µm × 3.1–3.8 µm.

Chemistry: Thallus K+ yellow, C-, P-, UV-; stictic acid detected in TLC.

Distribution: India (Arunachal Pradesh, Assam, Kerala, Sikkim, and West Bengal), Costa Rica, Malaysia, and Sri Lanka.

10. *Herpothallon echinatum* Aptroot, Lücking & Will-Wolf, *Biblioth. Lichenol*. 99: 38. 2009. (Arthoniaceae) (Image 10).

Specimen examined: LWG 35859, 18.ii.2018, Assam, Ngaon District, Jugijan, Na-Nath Archaeological Site, 26.033°N, 92.774°E, 71m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, greyish-white, firmly attached to the substratum, byssoid; hyothallus and prothallus white, byssoid; pseudoisidia numerous, crowded, cylindrical. Ascomata and pycnidia not seen.

Chemistry: Thallus K-, C-, P+ yellow, UV-; psoromic acid detected in TLC.

Distribution: India (Andaman Islands, Assam, and Sikkim) Australia, Costa Rica, Indonesia, Norfolk Islands, Papua New Guinea, Taiwan, and Thailand.

11. *Lecanographa rufa* (Müll. Arg.) Ertz., *Biblioth. Lichenol.* 102: 149. 2009.

Opegrapha rufa Müll. Arg., *Bot. Jb.* 20: 280. 1894. (Lecanographaceae) (Image 11a,b,c).

Specimen examined: LWG 35860, 08.ii.2017, Assam, Nagaon District, Samaguri, Suang Reserve Forest, Loong Soong Tea Estate, 26.369°N, 92.899°E, 109m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, areolate, whitish-grey. Ascomata lirellate, numerous, evenly distributed in the thallus, straight to often flexuose, unbranched, rarely with a single branch, disc highly exposed, covered with thick pruina; excipulum black, broadly continuous below the hypothecium; hymenium hyaline, I+ directly red; paraphysoids branched and anastomosing; epihymenium dark brown with pruina. Asci narrowly clavate, 8-spored; ascospores hyaline, transversely 3–5-septate, not constricted at septa, 19.3–22.6 µm × 3.6–5.3 µm.

Chemistry: Thallus K-, C-, P-; no lichen substance

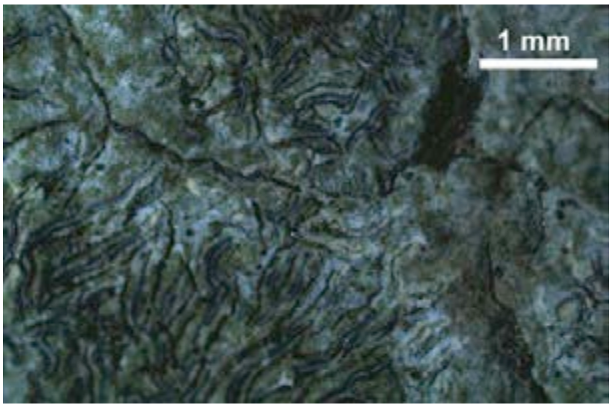

Image 9a. *Graphis sundarbanensis* Jagadeesh & G.P. Sinha. © Rupjyoti Gogoi.

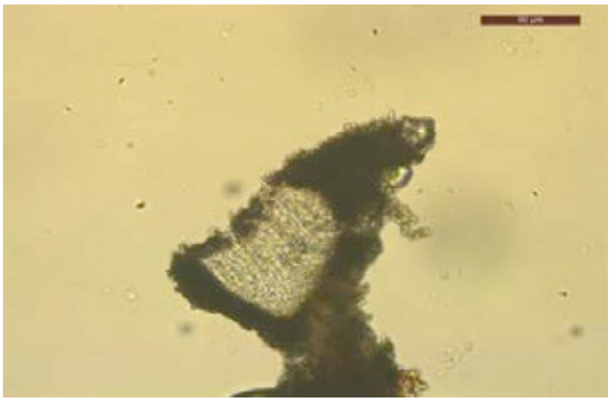

Image 9b. Longitudinal section of ascoma of *Graphis sundarbanensis* Jagadeesh & G.P. Sinha. © Rupjyoti Gogoi.

Image 9c. Ascospore of *Graphis sundarbanensis* Jagadeesh & G.P. Sinha. © Rupjyoti Gogoi.

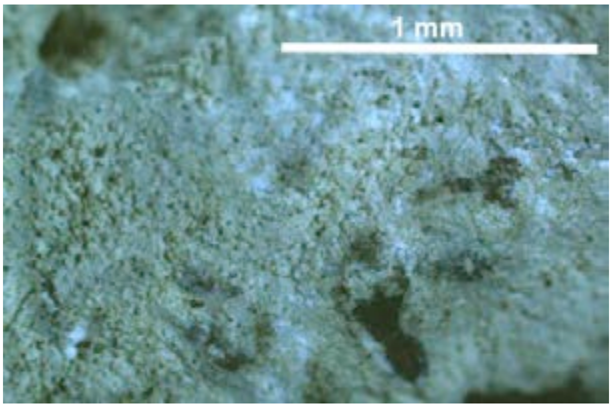

Image 10. *Herpothallon echinatum* Aptroot, Lücking & Will-Wolf. © Rupjyoti Gogoi.

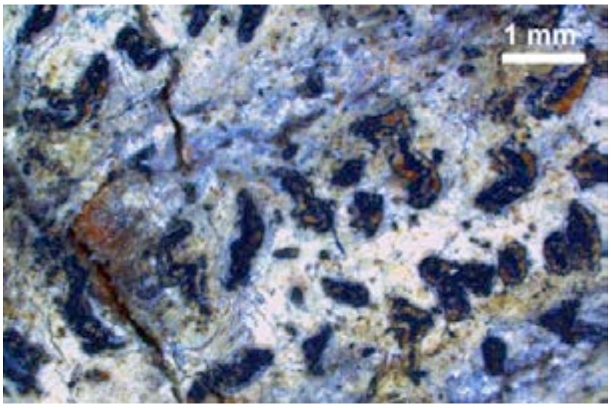

Image 11a. *Lecanographa rufa* (Müll. Arg.) Ertz. © Rupjyoti Gogoi.

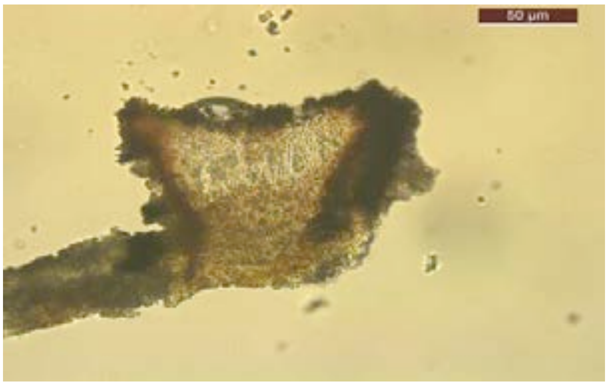

Image 11b. Longitudinal section of ascoma of *Lecanographa rufa* (Müll. Arg.) Ertz. © Rupjyoti Gogoi.

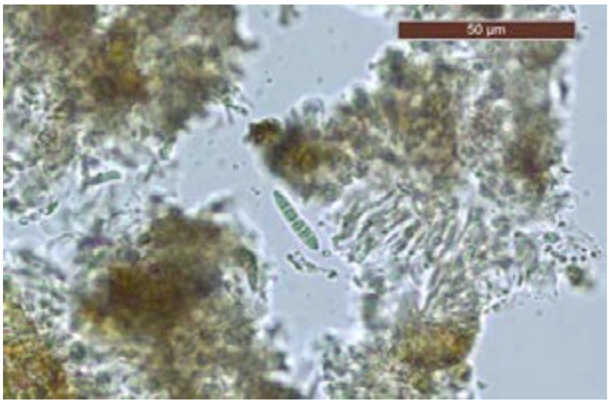

Image 11c. Ascospore of *Lecanographa rufa* (Müll. Arg.) Ertz. © Rupjyoti Gogoi.

detected in TLC.

Distribuition: India (Assam and West Bengal) and Tanzania.

12. *Letrouitia muralis* Hafellner, Nova Hedwigia 35: 695. 1983. (Letrouitiaceae) (Image 12a,b,c).

Specimen examined: LWG 35861, 10.i.2018, Assam, Nagaon District, Lanka, Lumding Reserve Forest, 25.875°N, 93.020°E, 130m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, verrucose, orange-yellow. Ascomata biatorine, scattered, rounded, sessile, constricted at base, disc brown, slightly concave or plane, margin distinct, prominent, concolorous with the thallus; hymenium hyaline. Asci clavate, 2–4-spored; ascospores hyaline, ellipsoidal, transversely 6–7-septate, with lenticular locules, 24.7–29.3 µm × 9.6–12.5µm.

Chemistry: Thallus and apothecia K+ purple, C-, P-; TLC not performed.

Distribution: India (Assam, Karnataka, and Tamil Nadu), Africa, Australia, and The Philippines.

13. *Myriotrema clandestinum* (Fée) Hale, *Mycotaxon* 11: 133. 1980. *Thelotrema clandestinum* Fée, *Essai Crypt. Ecorc.*: 90. 1837. (Graphidaceae) (Image 13a,b,c).

Specimen examined: LWG 35862, 18.ii.2018, Assam, Nagaon District, Samaguri, Suang Reserve Forest, Chapanala, 26.320°N, 92.904°E, 119m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, glossy, ashy grey, corticated. Ascomata immersed; hymenium hyaline, without collumella. Asci 8-spored; ascospores consistently, transversely 3-septate, hyaline, 10.1–13.7 µm × 3.5–5.4 µm.

Chemistry: Thallus K-, C-, P+ yellow, UV-; psoromic acid detected in TLC.

Distribution: India (Andaman & Nicobar Islands, Assam, Arunachal Pradesh, Karnataka, Kerala, Maharashtra, and Megahlaya), Australia, Colombia, El Salvador, Indonesia, New Caledonia, Philippines, Solomon Islands, Sri Lanka, Taiwan, and Venezuela.

Image 12a. *Letrouitia muralis* Hafellner. © Rupjyoti Gogoi.

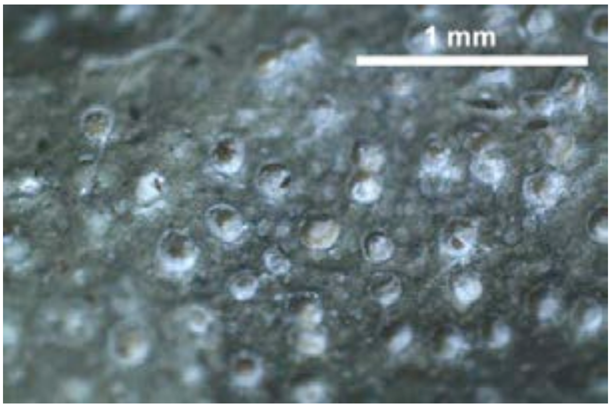

Image 13a. *Myriotrema clandestinum* (Fée) Hale. © Rupjyoti Gogoi.

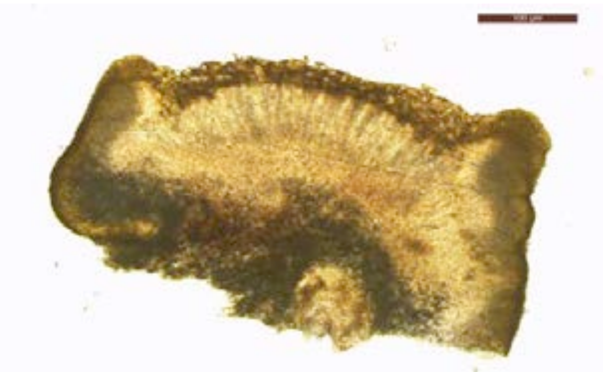

Image 12b. Longitudinal section of ascoma of *Letrouitia muralis* Hafellner. © Rupjyoti Gogoi.

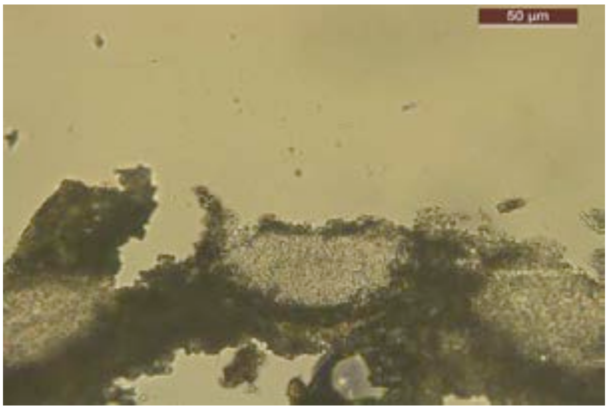

Image 13b. Longitudinal section of ascoma *Myriotrema clandestinum* (Fée) Hale. © Rupjyoti Gogoi.

Image 12c. Ascospore of *Letrouitia muralis* Hafellner. © Rupjyoti Gogoi.

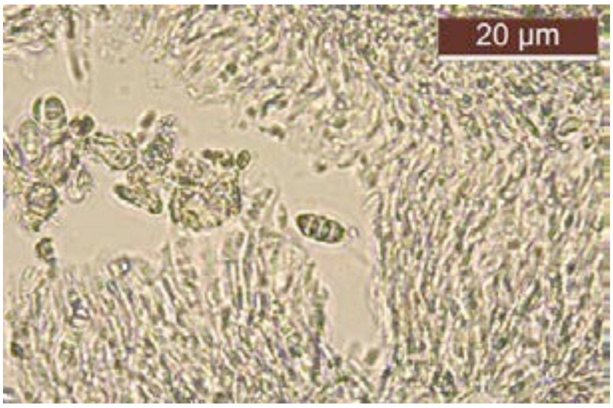

Image 13c. Ascospore of *Myriotrema clandestinum* (Fée) Hale. © Rupjyoti Gogoi.

14. *Opegrapha discolor* Vain., *Ann. Acad. Sci.Fenn*., Ser. A, 15(6): 276. 1921. (Opegraphaceae) (Image 14a,b,c).

Specimen examined: LWG 35863, 10.xii.2017, Assam, Nagaon District, Jamunamukh, Erakapili, 26.098°N, 92.745°E, 74m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, thin to inconspicuous, rimose, olive-green. Ascomatalirellate, short, variable, disc slit to ± open, epruinose; excipulum black, broadly continuous below the hypothecium; hymenium I+ red. Asci bitunicate, clavate, 8-spored; ascospores hyaline, transversely 3-septate, 13.3–13.9 µm × 2.7–3.9 µm, perispore ca. 1µm thick.

Chemistry: Thallus K-, C-, P+ yellow, UV-; no lichen

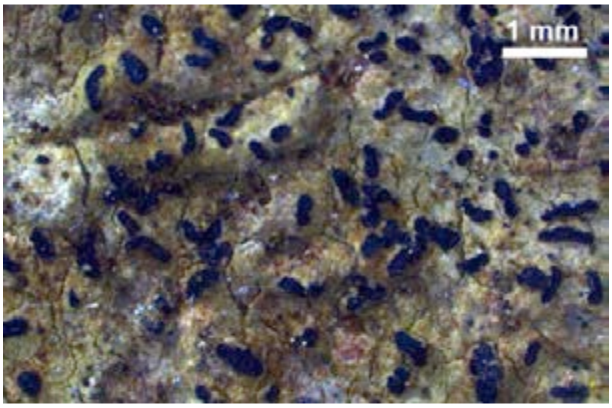

Image 14a. *Opegrapha discolor* Vain. © Rupjyoti Gogoi.

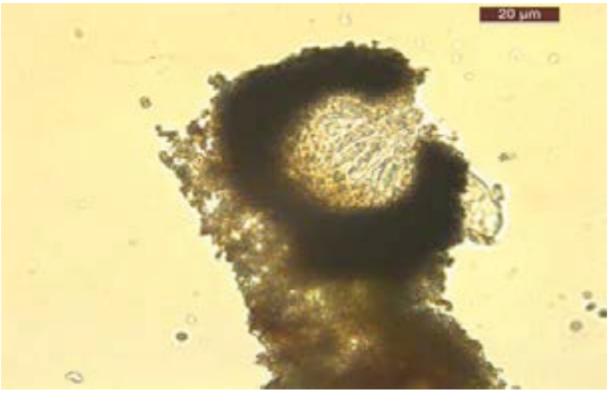

Image 14b. Longitudinal section of ascoma of *Opegrapha discolor* Vain. © Rupjyoti Gogoi.

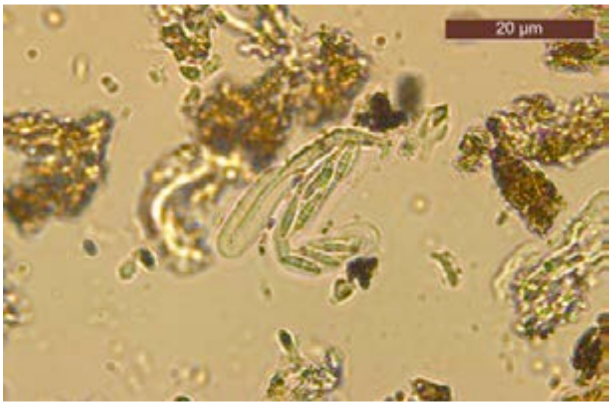

Image 14c. Ascospores of *Opegrapha discolor* Vain. © Rupjyoti Gogoi.

substance detected in TLC.

Distribution: India (Assam, Bihar, and West Bengal) and The Philippines.

15. *Opegrapha discolor* Vain., *Ann. Acad. Sci.Fenn.*, Ser. A, 15(6): 276. 1921. (Opegraphaceae) (Image 14a,b,c).

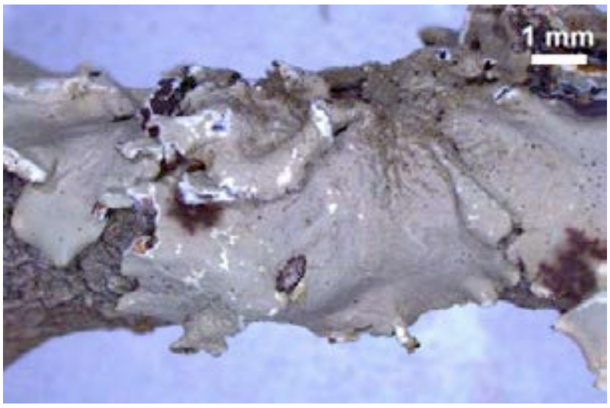

Image 15. *Parmotrema crinitoides* J.C. Wei. © Rupjyoti Gogoi.

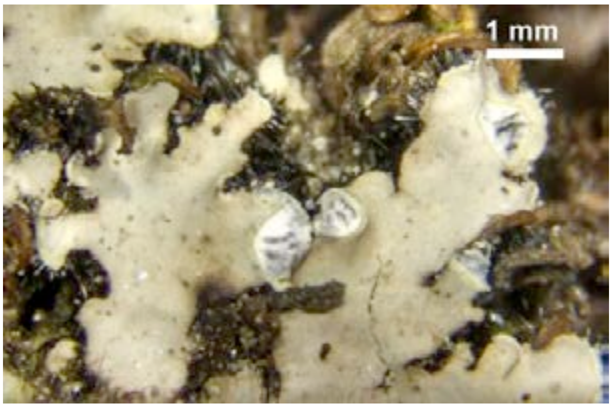

Image 16. *Phaeophyscia hispidula* (Ach.) Moberg. © Rupjyoti Gogoi.

Specimen examined: LWG 35863, 10.xii.2017, Assam, Nagaon District, Jamunamukh, Erakapili, 26.098°N, 92.745°E, 140m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, thin to inconspicuous, rimose, olive-green. Ascomatalirellate, short, variable, disc slit to ± open, epruinose; excipulum black, broadly continuous below the hypothecium; hymenium I+ red. Asci bitunicate, clavate, 8-spored; ascospores hyaline, transversely 3-septate, 13.3–13.9 µm × 2.7–3.9 µm, perispore ca. 1µm thick.

Chemistry: Thallus K-, C-, P+ yellow, UV-; no lichen substance detected in TLC.

Distribution: India (Assam, Bihar, and West Bengal) and The Philippines.

16. *Phaeophyscia hispidula* (Ach.) Moberg, *Bot. Not.* 131:260. 1978. 1810. *Parmelia hispidula* Ach., *Lich. Univ.*: 468. (Physciaceae) (Image 16).

Specimen examined: LWG 35865, 21.iv.2018, Assam, Nagaon District, Kaliabor, Hatimura, 26.613°N, 92.993°E, 134m, coll. Rupjyoti Gogoi.

Description: Thallus muscicolous, foliose, 3cm across, lobes 1.5–2.0 mm, upper side grey, soralia laminal, capitates, extending towards the margin; lower side black; rhizines long, black, projecting beyond the lobe; medulla white. Apothecia not seen.

Chemistry: Thallus K-, C-, P-, UV-; no lichen substance detected in TLC.

Distribution: India (Arunachal Pradesh, Assam, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Maharashtra, Manipur, Nagaland, Rajasthan, Sikkim, Tamil Nadu, and Uttarakhand), Australia, Bhutan, Nepal, New Zealand, and Taiwan.

17. *Porina eminentior* (Nyl.) P.M. McCarthy, *Lichenologist* 32(1): 42. 2000. *Thelenella eminentior* Nyl., *Annls. Sci. Nat., Bot.*, sér. 4, 15: 54. 1861. (Porinaceae) (Image 17a,b,c).

Specimen examined: LWG 35866, 05.ii.2017, Assam, Nagaon District, Samaguri, Suang Reserve Forest, Chapanala, 26.322°N, 92.904°E, 140m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, epiphloeodal, pale yellow, irregularly to rimose areolate, verruculose. Ascomata perithecia, hemispherical, numerous, emergent, concolorous with the thallus; ostiole apical; involucrellum yellowish-brown to orange-brown. Asci 8-spored; ascospores submuriform to muriform, transversely 7–8 septa, longitudinally 0–2 septa, 34.6–53.4 µm × 11.9–14.6 µm.

Chemistry: Thallus K-, C-, P-, UV-.

Distribution: India (Assam and Meghalaya), Australia, Brazil, Japan, New Caledonia, Papua New Guinea, The Philipinnes, and Vanuatu.

18. *Porina interstes* (Nyl.) Harm., *Bull. Séances Soc. Sci. Nancy,* sér. 3, 12: 126. 1911

Verrucaria interstes Nyl. *Bull. Soc. Linn. Normand.,* sér. 2, 2: 123. 1868. (Porinaceae) (Image 18a,b,c).

Specimen examined: LWG 35867, 10.xii.2017, Assam, Nagaon District, Hojai, Kumrakata Reserve Forest, 26.001°N, 92.779°E, 68m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, greenish-grey. Ascomata perithecia, numerous, ±4mm, solitary to aggregated, brownish to orange tinge, ostiole apical, peridium brownish black. Asci 8-spored, ascospores hyaline, transversely 7–15-septate, 42–43.6 µm × 5.0–5.5 µm.

Chemistry: Thallus K-, C-, P-, UV-.

Distribution: India (Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Goa, Karnataka, Kerala, Madhya Pradesh, Tamil Nadu, and West Bengal).

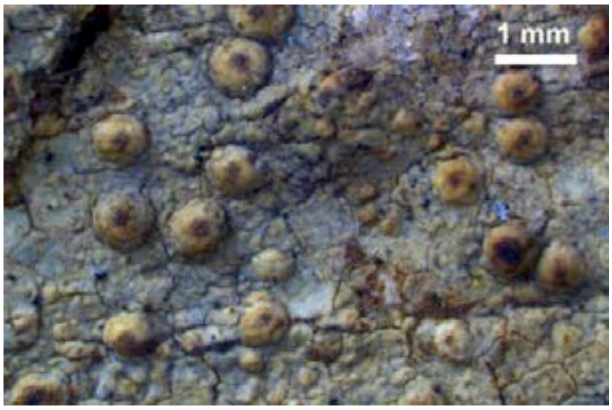

Image 17a. *Porina eminentior* (Nyl.) P.M. McCarthy. © Rupjyoti Gogoi.

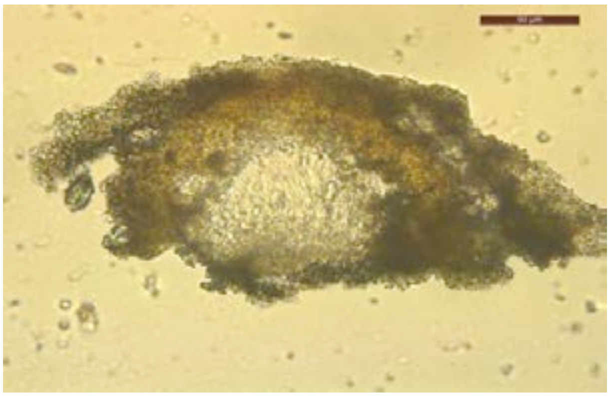

Image 17b. Longitudinal section of ascoma of *Porina eminentior* (Nyl.) P.M. McCarthy. © Rupjyoti Gogoi.

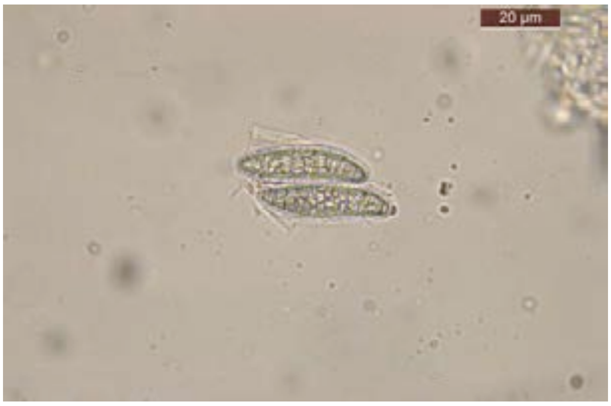

Image 17c. Ascospores of *Porina eminentior* (Nyl.) P.M. McCarthy. © Rupjyoti Gogoi.

19. *Porina mastoidella* (Nyl.) Müll. Arg., *Bot. Jahrb. Syst.* 6: 401. 1885. *Verrucaria mastoidella* Nyl., *Flora* 50: 8. 1867. (Porinaceae) (Image 19a,b,c).

Specimen examined: LWG 35868, 18.ii.2018, Assam, Nagaon District, Samaguri, Suang Reserve Forest, Chapanala, 26.335°N, 92.876°E, 118m, coll. Rupjyoti

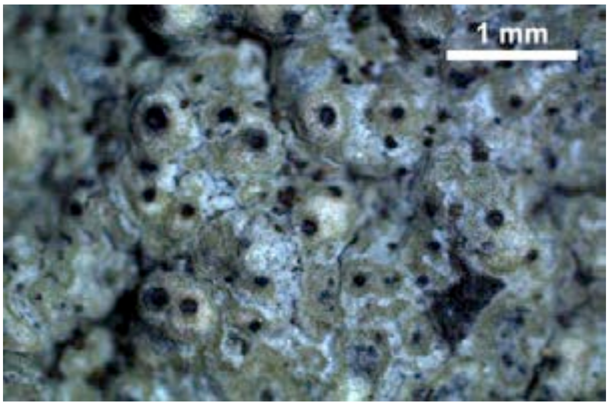

Image 18a. *Porina interstes* (Nyl.) Harm. © Rupjyoti Gogoi.

Image 19a. *Porina mastoidella* (Nyl.) Müll. Arg. © Rupjyoti Gogoi.

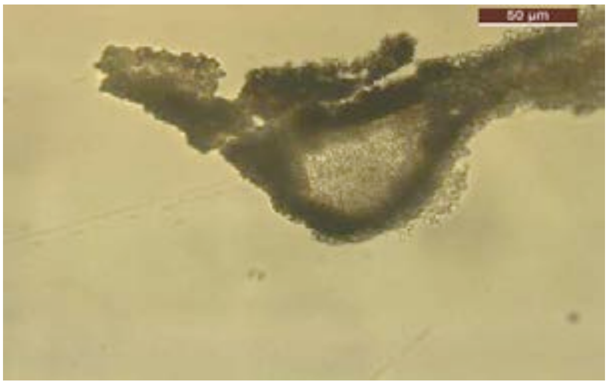

Image 18b. Longitudinal section of ascoma of *Porina interstes* (Nyl.) Harm. © Rupjyoti Gogoi.

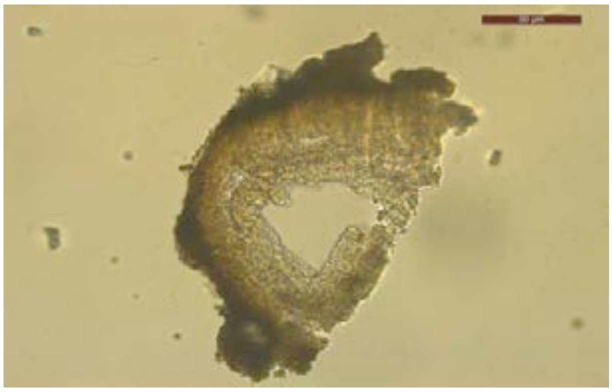

Image 19b. Longitudinal section of ascoma of *Porina mastoidella* (Nyl.) Müll. Arg. © Rupjyoti Gogoi.

Image 18c. Ascospores of *Porina interstes* (Nyl.) Harm. © Rupjyoti Gogoi.

Image 19c. Ascospore of *Porina mastoidella* (Nyl.) Müll. Arg. © Rupjyoti Gogoi.

Gogoi.

Description: Thallus corticolous, crustose, yellowish, border line black, ecorticate. Ascomata perithecia, brownish black to black, hemispherical, solitary, rarely grouped into 2–4, ostiole apical, excipulum K+ red, involurellum brown, hymenium inspersed. Asci, 8-spored, ascospores fusiform, 10.8–12.5 µm × 2.4–3.2 µm.

Chemistry: Thallus K-, C-, P-, UV-.

Distribution: India (Arunachal Pradesh, Assam, and West Bengal), Christmas Islands, Solomon Islands, Taiwan, and Vanuatu.

20. *Pyrenula submastophora* Ajay Singh & Upreti, *Geophytology* 17: 85. 1987. (Pyrenulaceae) (Image 20a,b,c).

Specimen examined: LWG 35869, 18.ii.2018, Assam, Nagaon District, Samaguri, Suang Reserve Forest, Chapanala, 26.335°N, 92.876°E, 101m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, brownish, border line black. Ascomata perithecia, emergent, solitary, rarely grouped, black, ostiole apical; hymenium hyaline, paraphysoids simple; peridium black, carbonized, collumellate at base. Asci clavate, 8-spored; ascospores brown, distoseptate, 3-septate, terminal lumina separated from exospores wall, 19.7–23.9 µm × 9.2–11.7 µm.

Chemistry: Thallus K-, C-, P-, UV-.

Distribution: India (Andaman & Nicobar Islands, Assam, and Kerala).

21. *Pyrenula thelomorpha* Tuck., *Gen. Lich.* (Amherst): 275. 1872. *Anthracothecium thelemorphum* (Tuck.) Zahlbr., *Cat. Lich. Univ.* 1: 469. 1922. (Pyrenulaceae) (Image 21a,b,c).

Specimen examined: LWG 35870, 24.iv.2018, Assam, Nagaon District, Jamunamukh, Erakapili, 26.098°N, 92.745°E, 74m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, epiphloeodal, greyish-brown. Ascomata perithecia, solitary to 2–4 confluent, black, emergent, peridium black, ostiole apical, ascomatal wall black, continuous below the hamathecium. Asci cylindrical, bitunicate, 6-spored; ascospores muriform, narrowly ellipsoidal, brown at maturity, distoseptate, 30.8–41.0 µm × 9.9–13.9 µm.

Chemistry: Thallus K-, C-, P-, UV-; no lichen substance detected in TLC.

Distribution: India (Assam, Karnataka, and West Bengal). Pantropical distribution.

22. *Rinodina oxydata* (A. Massal.) A. Massal., *Geneac. Lich.*: 19. 1854..*Mischoblastia oxydata* A. Massal., *Ric. Auton. Lich. Crost.*: 42. 1853. (Physciaceae) (Image 22a,b)

Specimen examined: LWG 35871, 10.xii.2017, Assam, Nagaon District, Jugijan, Rajbari Archaeological Site, 26.035°N, 92.787°E, 85m, coll. Rupjyoti Gogoi.

Description: Thallus saxicolous, crustose, olivaceous, areolate. Ascomata lecanorine, black; epihymenium brownish; hymenium hyaline. Asci 8-spored; ascospores brown, transversely 1-septate, *Mischoblastia* type, ovoid, 14.4–16.2 µm × 9.1–10.37 µm.

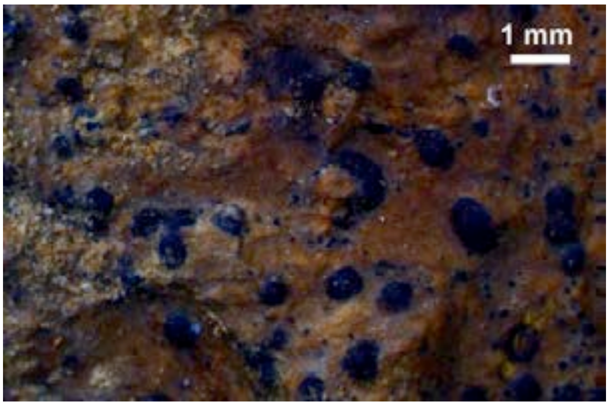

Image 20a. *Pyrenula submastophora* Ajay Singh & Upreti. © Rupjyoti Gogoi.

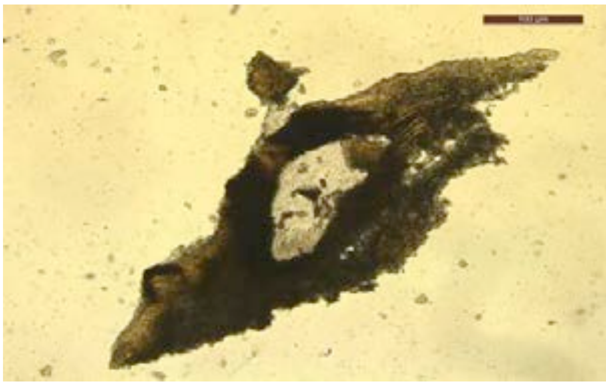

Image 20b. Longitudinal section of ascoma of *Pyrenula submastophora* Ajay Singh & Upreti. © Rupjyoti Gogoi.

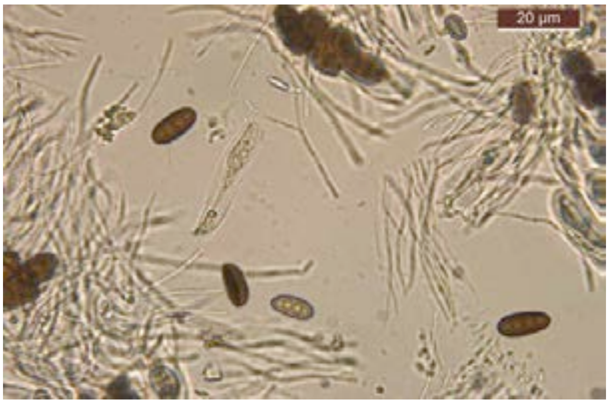

Image 20c. Ascospores of *Pyrenula submastophora* Ajay Singh & Upreti. © Rupjyoti Gogoi.

Chemistry: Thallus K+ yellow, C-, P-, UV-; no lichen substances detected in TLC.

Distribution: India (Assam, Madhya Pradesh, Tamil Nadu, Uttarakhand, and West Bengal), Bangladesh, Canary Island, Indonesia, Italy, and Japan.

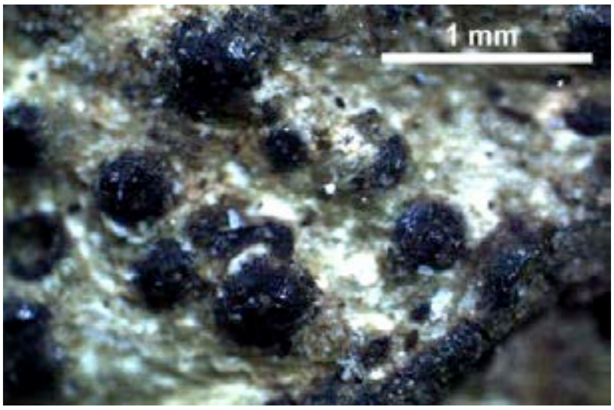

Image 21a. *Pyrenula thelomorpha* Tuck. © Rupjyoti Gogoi.

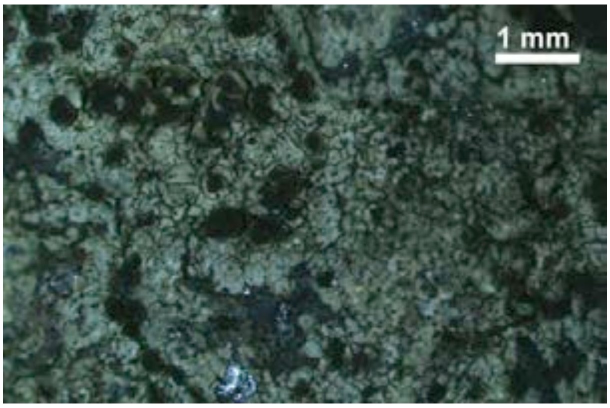

Image 22a. *Rinodina oxydata* (A. Massal.) A. Massal. © Rupjyoti Gogoi.

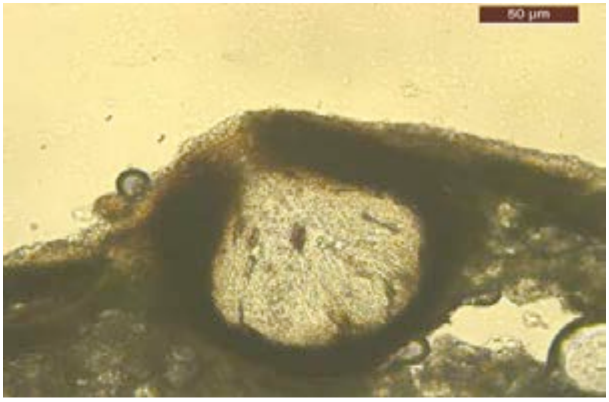

Image 21b. Longitudinal section of ascoma of *Pyrenula thelomorpha* Tuck. © Rupjyoti Gogoi.

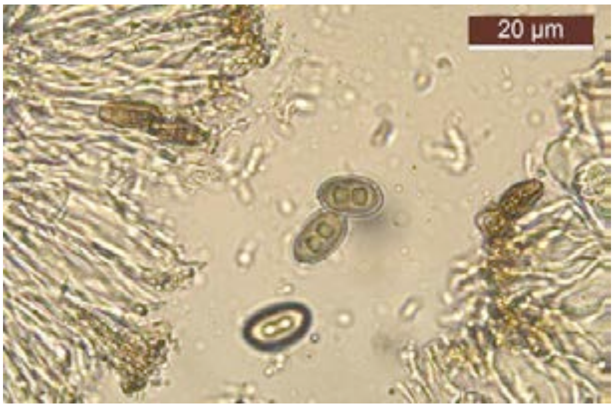

Image 22b. Ascospores of *Rinodina oxydata* (A. Massal.) A. Massal. © Rupjyoti Gogoi.

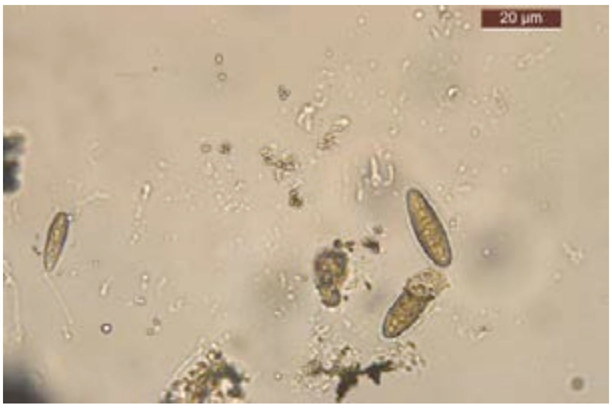

Image 21c. Ascospores of *Pyrenula thelomorpha* Tuck. © Rupjyoti Gogoi.

23. *Synarthonia bicolor* Müll. Arg., *Bull. Soc. R. Bot. Belg.* 30: 86. 1891. (Arthoniaceae) (Image 23a,b,c).

Specimen examined: LWG 35872, 18.ii.2018, Assam, Nagaon District, Nowgong College Campus, 26.348°N, 92.684°E, 84m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, greyish, border line brownish-black. Ascomata solitary when young, with white thalline margin without algal cells, turning into monocarpocentral synascomata and finally becoming pluri-carpocentralsynascomata forming a pseudostromatic structure, with a hardly visible white thalline margin, individual ascomata lirellate to rounded or irregular, pruinose; hymenium hyaline, I+ red, KI+ blue; paraphysoids branched and anastomosing. Asci 8-spored, *Arthonia*-type; ascospores hyaline, transversely 3–5-septate, 13.2–19.2 µm × 5.4–6.2 µm.

Chemistry: Thallus K-, C-, P-, UV+ yellow; lichexanthone detected in TLC.

Distribution: India (Assam and West Bengal) and Costa Rica.

24. *Zwackhia bonplandii* (Fée) Ertz, *Bull. Soc. Naturalistes Luxemb.* 113: 106. 2012. *Opegrapha bonplandii* Fée, *Essai Crypt. Exot. (Paris)*: 25. 1825 (1824). (Lecanographaceae) (Image 24a,b,c).

Specimen examined: LWG 35873, 19.i.2017, Assam, Nagaon District, Doboka Reserve Forest, 26.192°N,

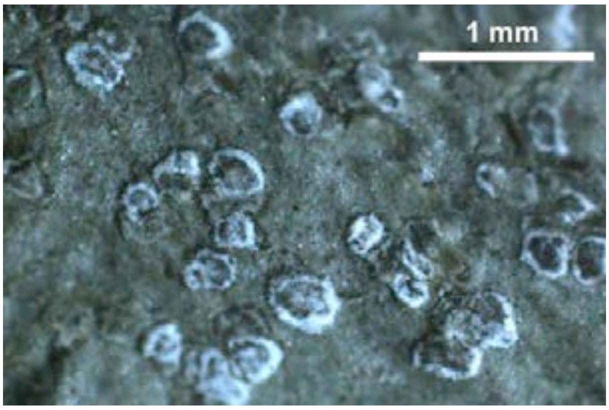

Image 23a. *Synarthonia bicolor* Müll. Arg. © Rupjyoti Gogoi.

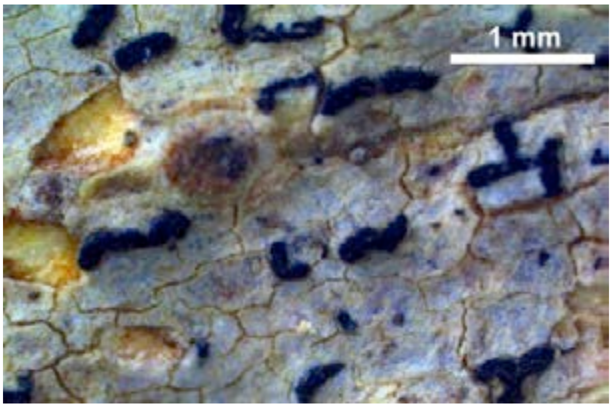

Image 24a. *Zwackhia bonplandii* (Fée) Ertz. © Rupjyoti Gogoi.

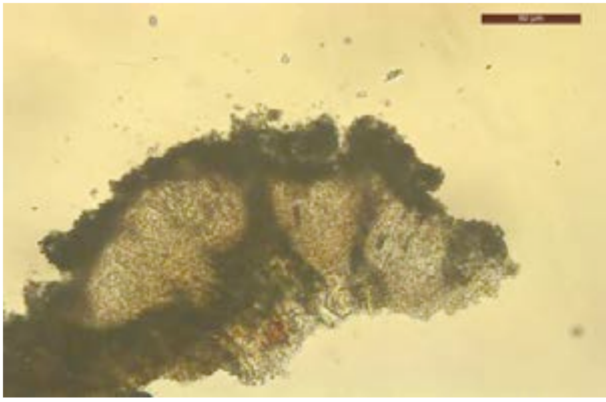

Image 23b. Longitudinal section of ascoma of *Synarthonia bicolor* Müll. Arg. © Rupjyoti Gogoi.

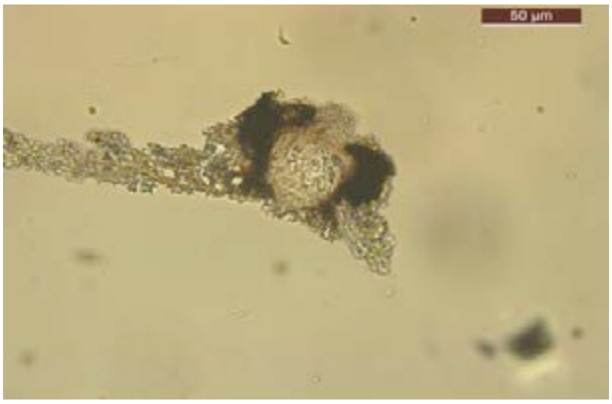

Image 24b. Longitudinal section of ascoma of *Zwackhia bonplandii* (Fée) Ertz. © Rupjyoti Gogoi.

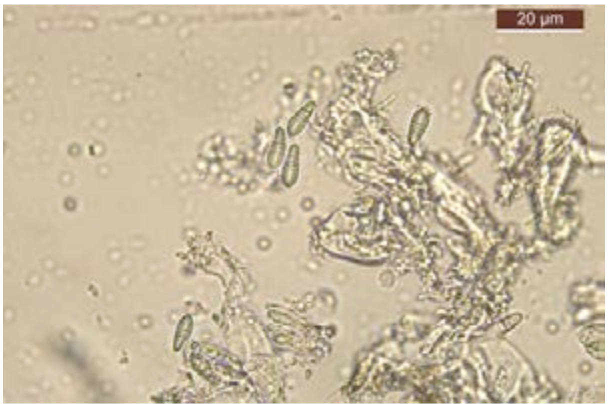

Image 23c. Ascospores of *Synarthonia bicolor* Müll. Arg. © Rupjyoti Gogoi.

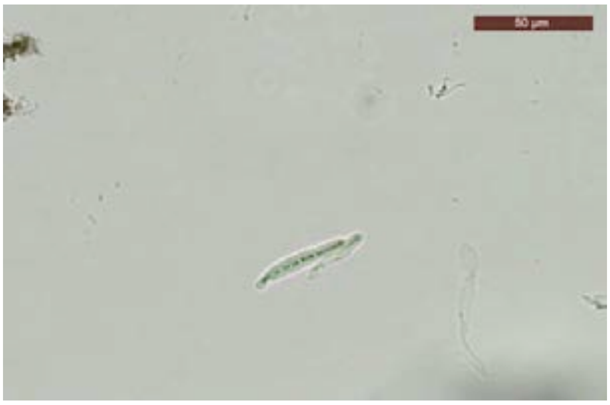

Image 24c. Ascospore of *Zwackhia bonplandii* (Fée) Ertz. © Rupjyoti Gogoi.

92.781°E, 136m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, thin to inconspicuous, surface smooth. Ascomata lirellate, scattered, numerous, rarely branched, emerged, straight to curved, epruinose, disc slit to ±exposed, black; excipulum carbonized, broadly continuous below the hypothecium; hymenium hyaline, not inspersed, I+ red; paraphysoidsbarnched and anastomosing. Asci clavate, 8-spored; ascospores hyaline, transversely 9–12-septate, fusiform, 40.1–60.7 µm × 4.7–6.1 µm, perispore ca. 1µm thick.

Chemistry: Thallus K-, C-, P-, UV-; no lichen substance

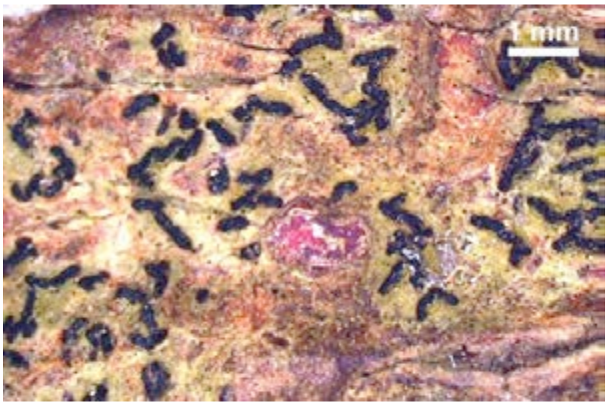

Image 25a. *Zwackhia viridis* (Ach.) Poetsch & Schied. © Rupjyoti Gogoi.

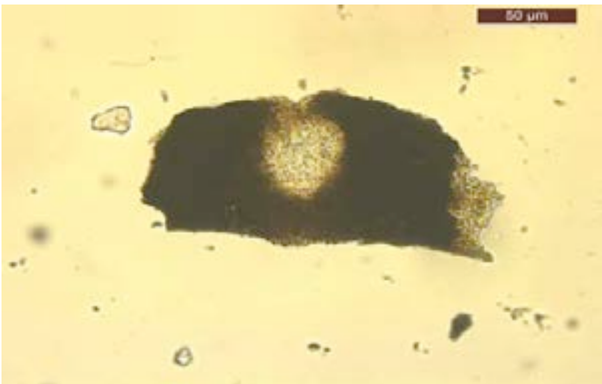

Image 25b. Longitudinal section of ascoma of *Zwackhia viridis* (Ach.) Poetsch & Schied. © Rupjyoti Gogoi.

Image 25c. Ascospore of *Zwackhia viridis* (Ach.) Poetsch & Schied. © Rupjyoti Gogoi.

detected in TLC.

Distribution: India (Andaman & Nicobar Islands, Assam, and West Bengal), Africa, Bermuda, Malaysia, New Zealand, and Thailand.

25. *Zwackhia viridis* (Ach.) Poetsch & Schied., *Syst. Aufz. Krypt. Pfl.*: 186. 1872. *Opegrapha rubella* var. *viridis* Ach., *Methodus*: 22. 1803. (Lecanographaceae) (Image 25a,b,c).

Specimen examined: LWG 35874, 18.ii.2018, Assam, Nagaon District, Samaguri, Suang Reserve Forest, Chapanala, 26.335°N, 92.876°E, 109m, coll. Rupjyoti Gogoi.

Description: Thallus corticolous, crustose, thin to inconspicuous, smooth to craked, border line dark brown. Ascomata lirellate, scattered, rarely aggregated, lirellae short, straight to flexuous, disc slit to ±open, epruinose; excipulum broadly continuous below the hypothecium; hymenium I+ red, hyaline, not inspersed; paraphysoids branched and anastomosing. Asci clavate, 8-spored; ascospores hyaline, transversely 7–10-septate, cells almost equal in size, 22.5–35.5 µm × 2.8–3.5 µm, perispore ca. 1µm thick.

Chemistry: Thallus K-, C-, P-, UV-; no lichen substance detected in TLC.

Distribution: India (Andaman & Nicobar Islands, Assam, Karnataka, and Manipur), Africa, Australia, France, Indonesia, La Réunion, Madagascar, Malaysia, Papua New Guinea, Republic of Korea, Sri Lanka, Taiwan, Thailand, and The Philippines.

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Study of nesting behaviour of Asian Paradise Flycatcher *Terpsiphone paradisi* (Aves: Passeriformes: Monorchidae) from southern West Bengal, India

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Abstract: The Asian Paradise Flycatcher has always been a flamboyant passerine to be photographed quite often throughout the Gangetic Bengal in India, but hardly any behavioural documentation is enlisted till date. The nesting behaviour of the subject bird encompassing its parental behaviours was studied on a wetland stretch of Ishapore, southern Gangetic Bengal. The present study mainly deals with the nesting behaviour, incubation activities, hatching, and parental care to fledging of a wild pair. The behavioural changes at par with the changing weather conditions and the neighbouring species too were studied.

Keywords: Barti Beel, behaviour, brooding, courting, fledging, hatching, incubation, Ishapore, parental care, Passeriformes.

The Asian Paradise Flycatcher *Terpsiphone paradisi* is a medium-sized passerine bird that inhabits forests and well-wooded habitats in different parts of Asia. It is a widespread resident in the Indian subcontinent and migrates seasonally. In West Bengal State in India, however, the species is a summer visitor (Grimmett et al. 2011; Rasmussen & Anderton 2012). Asian Paradise Flycatcher exhibits sexual dimorphism. Breeding pairs are monogamous. Being socially monogamous, both male and female take part in nest-building, incubation, brooding, and feeding of the young (Mizuta & Yamagishi 1998). It is relatively robust to habitat loss, evident from its appearance in forest edges and urban green spaces. Combined with its extraordinarily widespread distribution, it is not locally nor globally threatened and is currently rated as Least Concern (LC) by the International Union for the Conservation of Nature (IUCN 2019). Studies on the courtship, nesting, and feeding behaviour are available sparsely (Mizuta & Yamagishi 1998; Gokula & Vijayan 2003). Many sightings of this passerine variety were noted throughout the state but no information on its biology, ecology, or behaviour is available from the lower Gangetic plain despite a good number of photographic records. The present work aimed to study the behavioural aspects of the Asian Paradise Flycatcher in relation with courtship, nesting, and parental care from the southern part of West Bengal.

Study site

The study area was located near a wetland named Barti Beel (Bengali: lake; 22.782°N & 88.391°E) in Ishapore, North 24 Parganas, West Bengal. It is an

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Competing interests: The authors declare no competing interests.

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isolated place with very less human activities or disturbances. The forest covered a long range of mostly bamboo vegetation, with mango and guava trees lining a narrow mud path. Agricultural fields, ponds, and the wetland area are flooded during the monsoon.

Behaviour study

Observations were carried out from 05 June to 19 July 2017 on a single nest. The observations were made from a safe hide-out with proper camouflaged clothing and ambience. A considerable distance from the nest was maintained to avoid disturbances during observation. A pair of Olympus 8×40 DPS I binoculars and Nikon Coolpix P600 camera was used for documentation. Tree and nest heights and distances were measured by TruPulse 300 laser range finder. The girth of the tree at chest height was measured using a measuring tape. The birds were not marked, the size of the clutch was not measured, the and nest was not touched or brought down for measurement purposes even after being deserted by birds as chances remained for another couple to use the same.

Results and Discussion

The nest was built at a height of 4.15m in the branch of a Mango Tree *Mangifera indica* (height 6.35m, girth 179cm). The nest was chiefly made with twigs and spider webs on the end of a short branch. The nest was located on the third day of the observation period (Table 1). Initially, due to the height at which the nest was located and the tendency of the observers to not disturb the ambience and the condition of the nest, it was not approached directly. Hence, the presence of eggs was not confirmed in one go. A safe hideout at a distant bush resulted in locating/recording the repeated visits of the couple to the nest, with alternate (mostly, the female was engaged in the incubation process) intervals of sitting (assumed to be incubating the eggs), which confirmed the presence of eggs in the nest, though the number could not be confirmed then. Being socially monogamous, both male and female took part in nest-building, incubation, brooding, and feeding of the young. A sudden heavy rain on the 11th day of the observation period showed the fact that both the parents guarded the nest sitting at its edges spreading their wings. A stroll along the circumferential area where the nest was spotted confirmed the presence of nests of a few other species, namely Lineated Barbet *Megalaima lineate*, Coppersmith Barbet *M. haemacephala*, and Black-hooded Oriole *Oriolus xanthornus*. On the 27th day of the observation period, the peeping of a chick was observed inside the nest. The act of feeding the juvenile by the parents in alteration, mostly again by the female, facilitated the documentation. Right after six days (i.e., on the 33rd day of the observation period) from the first observation of the chick, two more chicks were observed inside. Since the nest was not hampered or no attempt was made to have an eye-level view of the nesting, the exact clutch size could not be determined; however, the number of chicks (here, three in number) could possibly give an overview of the same. The feeding behaviour was observed prior to fledging, even when the chicks were capable of coming out of the nest to the nearby twigs/branches. Feeding mostly comprised of ants, small insects, and damselflies torn into parts.

The breeding season of the species lasts from May to

Table 1. Chronology of the breeding cycle of Asian Paradise Flycatcher at Barti Beel in West Bengal, India.

Date	Day in the observation period	Observation at nest site
05.vi.2017	1	Three to four Asian Paradise Flycatcher (rufous) seen in the study area.
07.vi.2017	3	Nest was found.
12.vi.2017	8	Repeated attending of both the parent to the nest confirmed the presence of eggs.
14.vi.2017	10	Incubation was done by both the parents, the female being a bit more regular.
15.vi.2017	11	A sudden heavy rain showed the fact that both parents guarded the nest sitting at the edges spreading their wings.
18.vi.2017	14	Nests of Lineated Barbet, Coppersmith Barbet, and Black-hooded Oriole were observed in the circumferential reach of the studied spot.
01.vii.2017	27	One chick was observed.
04.vii.2017	30	Feeding mostly comprised of ants, small insects, and damselfly parts.
05.vii.2017	31	Both the parents were observed in the affair of feeding.
07.vii.2017	33	Two more chicks were observed peeping.
19.vii.2017	45	Feeding behaviour was observed prior to fledging, even when the chicks were capable to come out of the nest to nearby twigs/branches.

Image 1. Asian Paradise Flycatchers observed at Barti Beel in West Bengal, India: A - the female parent visiting the nest, perching on the brim of the nest | B - female parent observed sitting inside the nest, incubating the egg(s) | C - peeping of a chick | D - peeping of two more chicks | E - feeding of insects, damselflies, and larvae torn apart by the parent birds (mostly female) to the chicks | F & G - a young bird that recently fledged but is still dependent upon parental care for feeding | H - the onset of the colouration of the feathers on the sub-adult bird, confirming its rufous morph | I - the newly attained adulthood of the bird. © Nilemesh Das.

July; in this study, it started in June and ended by the end of July. The incubation period lasts 14–16 days and the nestling period 9–12 days (Mizuta & Yamagishi 1998), though our study recorded 23–26 days of incubation. Three eggs were laid in the neat cup nest on the end of a low branch. Chicks hatched in about 21–23 days.

In general, most of the studies showed lower breeding success in tree cavities compared to nest boxes (van Balen et al. 1982; Nilsson 1986; East & Perrins 1988; Alatalo et al. 1990; Lundberg & Alatalo 1992). Contrary to these studies, Mitrus (2003) and Czeszczewik (2004) reported higher breeding success in tree cavities than in nest boxes. In our study, reproductive success was 100% as we could observe the juveniles grow up to their adulthood and hovering around, though further such documentation or spotting was not carried out.

The site selection for nesting plays a crucial role in the success of the progeny. Nests built in the close proximity of a breeding pair of predatory birds like treepies and drongos often results in a significant reproductive success, where predation poses one of the major threats to the chicks (Nolan 1963; Ricklefs 1969). In our study, the nestlings of Lineated Barbet and Coppersmith Barbet pairs were seen at an approximate circumference of 60m and that of a Black-hooded Oriole at about 150m.

The breeding season for the non-migratory subspecies *affinis* is March–July, while for the migratory species *incei* it is May–July. Males are highly territorial and do not tolerate intruders. Breeding pairs are monogamous and the nest is build together but mainly by the female, who lays three to four eggs in the nest (Mizuta & Yamagishi 1998). In our study, however, we found that though both the parents were involved in nest-making, the feeding part was mostly carried out by the female, with the intervention of the male occasionally. During a sudden torrential rain, both the parents were seen guarding the nest and the chicks with their wings wide open.

The Asian Paradise Flycatcher primarily consumes small winged insects such as flies, bugs, and beetles, but is known to occasionally feed on spiders as well as larger insects such as Praying Mantises, moths, and butterflies by battering them to death and consuming the thorax and abdomen (Gokula & Vijayan 2003). The present study observed a similar set of pieces of damselflies, ants, and larvae being fed to the chicks by the parent birds. The birds usually perch high on a shade-covered branch, sallying out to catch insects on the wing and returning to the perch to consume them, often singly or in pairs (del Hoyo et al. 2006). Here, the nest was constructed on a twig which was about 50% shade-covered, with the parent birds perching on the edges of the brim of the nest.

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A checklist of fish species from three rivers in northwestern Bangladesh based on a seven-year survey

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Abstract: Bangladesh is rich in freshwater biodiversity, but information on riverine fish diversity is lacking. This study represents a complete list of fish species of Dhepa, Punarbhaba, and Atrai rivers of Bangladesh based on surveys carried out for seven years, from 2009 to 2016. A total of 121 species belonging to 80 genera and 33 families were recorded, of which Cyprinidae was the most dominant family representing 24 species. A total of 42 threatened species and 10 exotic species were collected during the survey. This study highlights that Dhepa, Punarbhaba, and Atrai are critical habitats for many conservation-concern fish species, and reveals the need for developing suitable conservation and management plans for the future.

Keywords: Atrai River, Dhepa River, exotic fish, freshwater fish, Punarbhaba River, threatened species.

Freshwater biodiversity constitutes a vitally important component of the planet, with relatively higher species richness than terrestrial and marine ecosystems (Gleick 1996). Bangladesh is rich in freshwater fish diversity with 253 species of which 64 are categorized as threatened (IUCN 2015). The natural habitats of the majority of the freshwater species are rivers (~230), their tributaries, and adjacent 'beels' (a lake-like wetland with static water).

The northwestern part of Bangladesh is traversed by Dhepa, Punarbhaba, and Atrai rivers which are considered hotspots of some small indigenous fish species. The information on the availability of fish species in these rivers, however, is lacking in scientific literature, and

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considerable variations in species diversity are known to exist between different seasons and years (Shahadat et al. 2012). This study aims to provide a comprehensive list of the species available in the Dhepa, the Punarbhaba, and the Atrai rivers of northwestern Bangladesh to facilitate river management and biodiversity conservation.

Materials and Methods

Data were collected as part of three projects conducted from 2009 to 2016 at Hajee Mohammad Danesh Science and Technology University, Dinajpur. The survey included monthly visits to fishing spots and local markets (bazaars) adjacent to the rivers. The sites were in Punarbhaba River (25.628°N & 88.618°E; 25.595°N & 88.614°E; 25.646°N & 88.620°E), Atrai River (25.718°N & 88.739°E; 25.538°N & 88.759°E; 25.871°N & 88.719°E), Dhepa River (25.703°N & 88.635°E; 25.783°N & 88.672°E; 25.652°N & 88.629°E), Dhepa River Fish Sanctuary (25.865°N & 88.665°E), Bahadur Bazaar (25.626°N & 88.633°E), Rail Bazaar (25.636°N & 88.643°E), Birgang Bazaar (25.862°N & 88.656°E), and Khanshama Bazaar (25.926°N & 88.727°E).

Fish species were identified by experienced fish biologists (Mohammad Shaifuddin Shah, Mostafa Ali Reza Hossain, Imran Parvez, and Mohammad Mahbubul Hassan) based on morphometric characters and meristic counts mentioned in Talwar & Jhingran (1991) and Rahman (2005). Updated taxonomic names follow Eschmeyer et al. (2018). The extinction risk and conservation status of the collected fishes follow IUCN (2015).

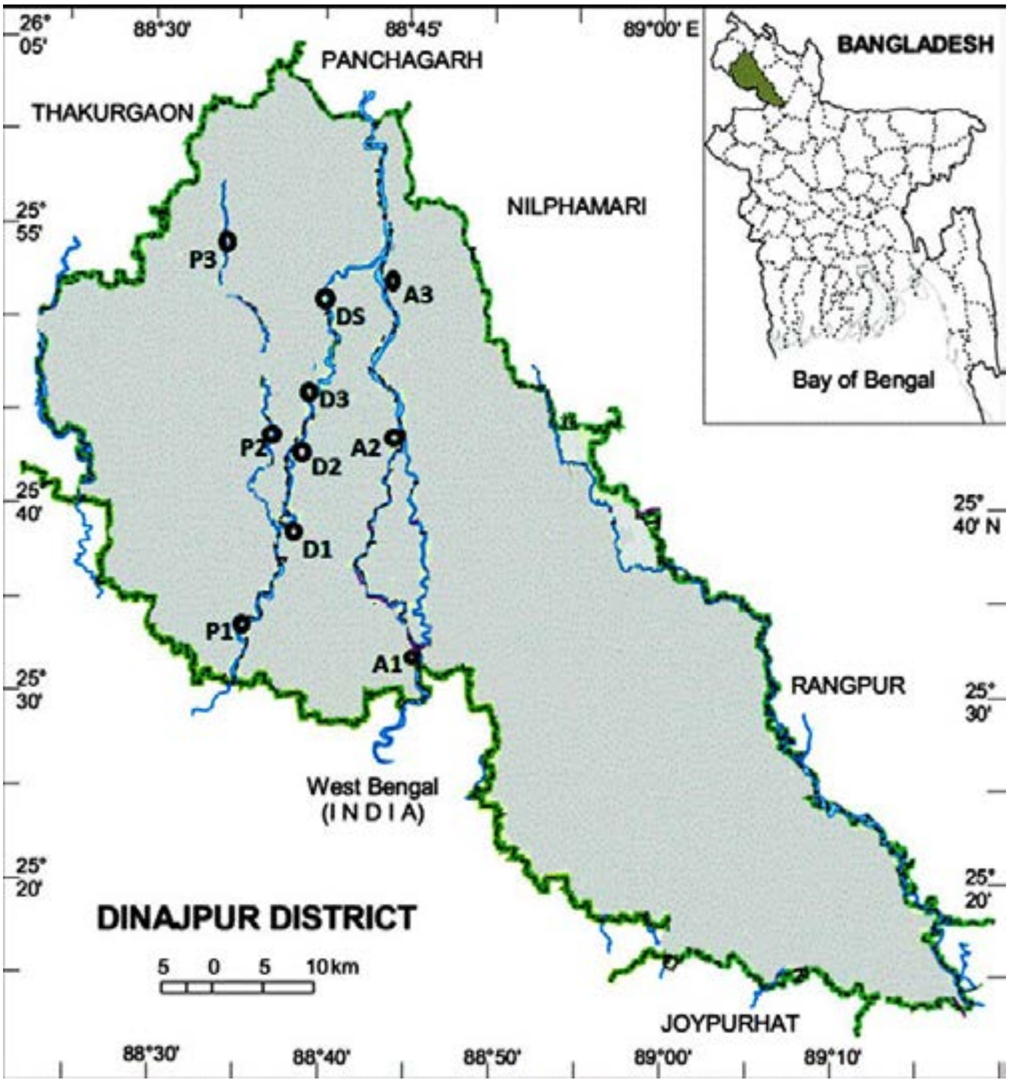

Figure 1. Locations of rivers in northwestern Bangladesh from which fish species were collected: P1, P2 & P3 - three sites of Punarbhaba River | D1, D2 & D3 - three sites of Dhepa River | A1, A2 & A3 - three sites of Atrai River.

Results

A total of 121 species (including 10 exotic species) belonging to 80 genera and 33 families were recorded during the study and are listed together with details of their IUCN status and habitats in Tables 1 and 2.

Cyprinidae was the most dominant family (24 species) followed by Danionidae (22 species) and Bagridae (10 species). Four species each belonged to the families Channidae, Mastacembelidae, Ambassidae, Siluridae, and Cobitidae and three species each to Psilorhynchidae and Ailiidae (Fig. 2).

Of the 111 indigenous species, 42 species (32.8%) were threatened, of which four species were listed as Critically Endangered, 24 as Endangered, and 14 as Vulnerable in the National Red List of Bangladesh (IUCN 2015; Fig. 3).

Discussion

This study provides the first comprehensive list of fish species availability in Dhepa, Punarbhaba, and Atrai rivers of northwestern Bangladesh. Cyprinidae dominated the species richness, a result similar to other freshwater ecosystems in Bangladesh (Rahman et al. 2012; Galib et al. 2013; Hasan et al. 2013; Chaki et al. 2014).

We also recorded 10 exotic species, namely *Cyprinus carpio, Hypophthalmichthys nobilis, Barbonymus gonionotus, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Mylopharyngodon piceus, Hypostomus plecostomus, Clarius gariepinus, Oreochromis mossambicus*, and *Pangasianodon hypopthalmus*. Although exotic species were introduced into Bangladesh to increase aquaculture production,

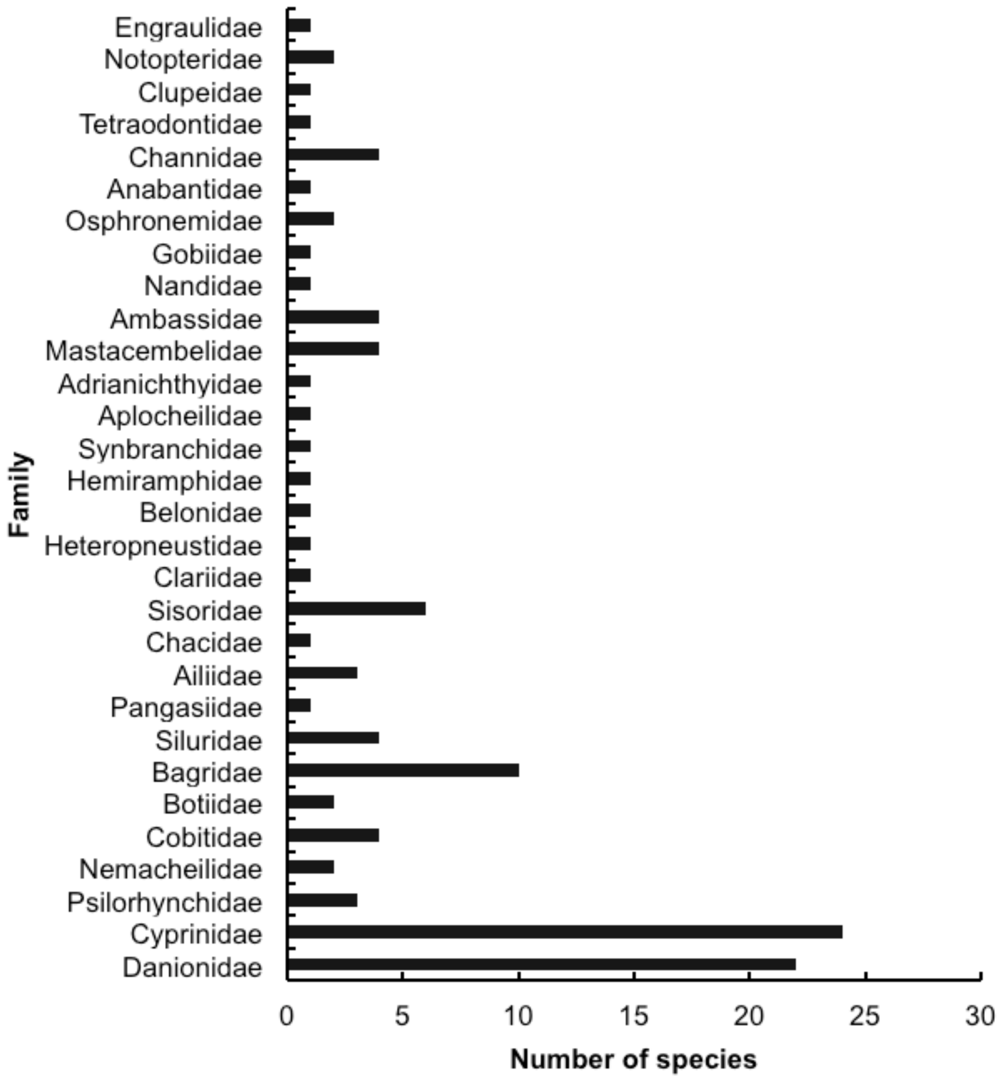

Figure 2. Number of fish species within different families collected from 2009 to 2016 in Punarbhaba, Dhepa, and Atrai rivers of northwestern Bangladesh.

Table 1. Indigenous fish species found in Punarbhaba, Dhepa, and Atrai rivers in northwestern Bangladesh from 2009 to 2016 (IUCN status: CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern, DD = Data Deficient, NE = Not Evaluated; '+' indicates presence and '-' indicates absence of species).

Family	Common name	Scientific name	Local name	Global status (IUCN 2015)	National status (IUCN 2015)	Presence/ absence in rivers and sanctuary			
						Punarbhaba	Dhepa	Atrai	Sanctuary
Danionidae	Jaya	*Cabdio jaya* (Hamilton, 1822)	Jaya	NE	LC	+	+	+	+
	Morari	*C. morar* (Hamilton, 1822)	Morari	NE	VU	+	+	+	+
	Mola Carplet	*Amblypharyngodon mola* (Hamilton, 1822)	Mola	LC	LC	-	+	-	+
	Indian Carplet	*A. microlepis* (Bleeker, 1853)	Mola	NE	LC	-	+	-	+
	Barred Barila	*Barilius barila* (Hamilton, 1822)	Barali	LC	DD	+	+	+	+
	Shacra Baril	*B. shacra* (Hamilton, 1822)	Koksa	LC	LC	+	-	+	-
	Hamilton Barila	*B. bendelisis* (Hamilton, 1807)	Joia	LC	EN	+	+	+	+
	Vagra Baril	*B. vagra* (Hamilton, 1822)	Vagra	LC	EN	+	-	+	-
	Barna Baril	*Opsarius barna* (Hamilton, 1822)	Bani Koksa	LC	EN	-	-	+	+
	Tileo Baril	*O. tileo* (Hamilton, 1822)	Tila	LC	EN	-	+	+	+
	Bengala Barb	*Bengala elanga* (Hamilton, 1822)	Along	LC	EN	-	+	-	+
	Silver Hatchlet Chela	*Chela cachius* (Hamilton, 1822)	Chep Chela	LC	VU	+	-	+	+
	Indian Glass Barb	*Laubuca laubuca* (Hamilton, 1822)	Labuca	LC	VU	+	+	+	+
	Zebra Danio	*Danio rerio* (Hamilton, 1822)	Anju	LC	NT	-	+	+	+
	Sind Danio	*Devario devario* (Hamilton, 1822)	Chap Chela	LC	LC	+	+	+	+
	Flying Barb	*Esomus danrica* (Hamilton, 1822)	Darkina	NE	DD	-	+	+	+
	Trout Barb	*Raiamas bola* (Hamilton, 1822)	Bhol	LC	EN	-	+	+	+
	Slender Rasbora	*Rasbora daniconius* (Hamilton, 1822)	Darkina	LC	LC	+	+	+	+
	Gangetic Scissortail Rasbora	*R. rasbora* (Hamilton, 1822)	Darkina	LC	EN	-	-	+	+
	Large Razorbelly Minnow	*Salmostoma bacaila* (Hamilton, 1822)	Katari	LC	DD	+	+	+	+
	Fine Scale Razorbelly Minnow	*S. phulo* (Hamilton, 1822)	Ful Chela	LC	NT	+	+	+	+
	Gora Chela	*Securicula gora* (Hamilton, 1822)	Gora Chela	LC	NT	+	+	+	+

Family	Common name	Scientific name	Local name	Global status (IUCN 2015)	National status (IUCN 2015)	Presence/ absence in rivers and sanctuary			
						Punarbhaba	Dhepa	Atrai	Sanctuary
Cyprinidae	Kalabans	*Bangana dero* (Hamilton, 1822)	Kursha	LC	DD	+	-	+	+
	Catla	*Gibelion catla* (Hamilton, 1822)	Katal	NE	LC	+	+	+	+
	Gotyla	*Garra gotyla* (Gray, 1830)	Ghor poia	LC	EN	-	-	+	-
	Chaguni	*Chagunius chagunio* (Hamilton, 1822)	Jarua	LC	VU	+	+	+	+
	Reba Carp	*Gymnostomus ariza* (Hamilton, 1807)	Korki	LC	NT	+	+	+	+
	Pangusia Labeo	*Labeo pangusia* (Hamilton, 1822)	Ghora Muikkha	NT	EN	-	-	+	-
	Kuria Labeo	*L. gonius* (Hamilton, 1822)	Ghannya	LC	NT	+	+	+	+
	Angra Labeo	*L. angra* (Hamilton ,1822)	Angrot	LC	VU	+	+	+	+
	Bata Labeo	*L. bata* (Hamilton, 1822)	Bata	LC	LC	+	+	+	+
	Boga Labeo	*L. boga* (Hamilton, 1822)	Bhangan	LC	CR	-	+	-	+
	Black Rohu	*L. calbasu* (Hamilton, 1822)	Kalibaus	LC	LC	+	+	+	+
	Rohu Carp	*L. rohita* (Hamilton, 1822)	Rui	LC	LC	+	+	+	+
	Hillstream Carp	*Tariqilabeo latius* (Hamilton, 1822)	Kala bata	LC	EN	-	+	-	+
	Kosuati	*Oreichthys cosuatis* (Hamilton, 1822)	Kosuati	NE	EN	-	+	+	+
	Cotio	*Osteobrama cotio* (Hamilton, 1822)	Dhela	LC	VU	+	+	+	+
	Olive Barb	*Systomus sarana* (Hamilton, 1822)	Sarpunti	LC	NT	+	+	+	+
	Swamp Barb	*Puntius chola* (Hamilton, 1822)	Chalapunti	LC	LC	+	+	+	+
	Pool Barb	*P. sophore* (Hamilton 1822)	Jatpunti	LC	LC	+	+	+	+
	One-spot Barb	*P. terio* (Hamilton, 1822)	Teri Punti	LC	LC	+	+	+	+
	Ticto Barb	*Pethia ticto* (Hamilton, 1822)	Tit Punti	LC	VU	+	+	+	+
	Glass Barb	*P. guganio* (Hamilton, 1822)	Mola Punti	LC	LC	+	+	+	+
	Spotted Barb	*P. phutunio* (Hamilton, 1822)	Phutani Punti	LC	LC	+	+	+	+
	Rosy Barb	*P. conchonius* (Hamilton, 1822)	Kanchan Punti	LC	LC	+	+	+	+
	Golden Barb	*P. gelius* (Hamilton, 1822)	Gilipunti	LC	NT	-	-	-	+
Psilorhynchidae	Balitora Minnow	*Psilorhynchus balitora* (Hamilton, 1822)	Balitora	LC	LC	+	+	+	+
	Rainboth Minnow	*P. nudithoracicus* Tilak & Husain, 1980	Balitora	DD	DD	+	+	+	+
	River Stone Carp	*P. sucatio* (Hamilton, 1822)	Balitora	LC	NT	+	+	+	+
Nemacheilidae	Sand Loach	*Paracanthocobitis botia* (Hamilton, 1822)	Balichata	LC	LC	+	+	+	+
	Corica Loach	*Nemacheilus corica* (Hamilton, 1822)	Korica	LC	EN	+	+	+	+

Family	Common name	Scientific name	Local name	Global status (IUCN 2015)	National status (IUCN 2015)	Presence/ absence in rivers and sanctuary			
						Punarbhaba	Dhepa	Atrai	Sanctuary
Cobitidae	Guntea Loach	*Lepidocephalichthys guntea* (Hamilton, 1822)	Puiya	LC	LC	+	+	+	+
	Loktak Loach	*L. irrorata* Hora, 1921	Puiya	LC	VU	+	+	+	+
	Annandale Loach	*L. annandalei* Chaudhuri, 1912	Puiya	LC	VU	+	+	+	+
	Gongota Loach	*Canthophrys gongota* (Hamilton, 1822)	Pahari Gutum	LC	NT	+	+	+	+
Botiidae	Bengal Loach	*Botia dario* (Hamilton, 1822)	Rani	LC	EN	+	-	+	+
	Y-Loach	*B. lohachata* Chaudhuri, 1912	Rani	NE	EN	+	-	+	+
Bagridae	Dwarf Catfish	*Batasio tengana* (Hamilton, 1822)	Tengra	LC	EN	-	-	+	-
	Menoda Catfish	*Hemibagrus menoda* (Hamilton, 1822)	Gang Tengra	LC	NT	+	-	-	+
	Day's Mystus	*Mystus bleekeri* (Day, 1877)	Gulsha Tengra	LC	LC	-	-	+	+
	Gangetic Mystus	*M. cavasius* (Hamilton, 1822)	Kabashi Tengra	LC	NT	+	+	+	+
	Striped Dwarf Catfish	*M. tengara* (Hamilton, 1822)	Bujri Tengra	LC	NT	+	+	+	+
	Gulio Catfish	*M. gulio* (Hamilton, 1822)	Nuna Tengra	LC	NT	+	+	+	+
	Striped River Catfish	*M. vittatus* (Bloch, 1794)	Tengra	LC	NT	+	+	+	+
	Rita	*Rita rita* (Hamilton, 1822)	Rita	LC	EN	-	+	+	+
	Long-whiskered Catfish	*Sperata aor* (Hamilton, 1822)	Ayre	LC	VU	+	+	+	+
	Giant River Catfish	*S. seenghala* (Sykes, 1839)	Guijjaayre	LC	VU	+	+	+	+
Siluridae	Two-spot Glass Catfish	*Ompok bimaculatus* (Bloch, 1794	Kanipabda	NT	EN	-	-	+	+
	Two-stripe Pabda Catfish	*O. pabda* (Hamilton, 1822)	Madhu Pabda	NT	EN	-	+	-	+
	Pabo Catfish	*O. pabo* (Hamilton, 1822)	Kala Pabda	NT	CR	-	+	-	+
	Freshwater Shark	*Wallago attu* (Bloch & Schneider, 1801)	Boal	NT	VU	+	+	+	+
Pangasiidae	Pungas	*Pangasius pangasius* (Hamilton, 1822)	Pangas	LC	EN	-	+	-	+
Ailiidae	Gangetic Ailia	*Ailia coila* (Hamilton, 1822)	Baspata	NT	LC	+	+	+	+
	Vacha	*Clupisoma garua* (Hamilton, 1822)	Bacha	NE	EN	+	+	+	+
	Murius Vacha	*Eutropiichthys murius* (Hamilton, 1822)	Muri Bacha	LC	LC	-	+	-	+
Chacidae	Square-head Catfish	*Chaca chaca* (Hamilton, 1822)	Chaka	LC	EN	+	+	-	+
Sisoridae	Devil Catfish	*Bagarius bagarius* (Hamilton, 1822)	Baghair	NT	CR	+	-	+	+
	Clown Catfish	*Gagata cenia* (Hamilton, 1822)	Couwa	LC	LC	+	+	+	+
	Gangetic Gagata	*G. gagata* (Hamilton, 1822)	Gang Tengra	LC	LC	+	+	+	+
	Sisor Catfish	*Sisor rabdophorus* Hamilton, 1822	Sai Sore	LC	CR	+	-	+	+
	Kosi Hara	*Erethistes hara* (Hamilton, 1822)	Kultakanti	LC	LC	+	+	+	+
	Conta Catfish	*Conta conta* (Hamilton, 1822)	Hara Machh	NE	NT	-	+	+	+

Family	Common name	Scientific name	Local name	Global status (IUCN 2015)	National status (IUCN 2015)	Presence/ absence in rivers and sanctuary			
						Punarbhaba	Dhepa	Atrai	Sanctuary
Clariidae	Walking Catfish	*Clarias magur* (Hamilton, 1822)	Magur	LC	LC	+	+	+	+
Heteropneustidae	Stinging Catfish	*Heteropneustes fossilis* (Bloch, 1794)	Shing	LC	LC	+	+	+	+
Belonidae	Freshwater Garfish	*Xenentodon cancila* (Hamilton, 1822)	Kankila	NE	LC	+	+	+	+
Hemiramphidae	Congaturi Halfback	*Hyporhamphus limbatus* (Valenciennes, 1847)	Ekthoata	NE	LC	+	+	+	+
Synbranchidae	Freshwater Mud Eel	*Monopterus cuchia* (Hamilton, 1822)	Kuchia	VU	VU	+	+	+	+
Aplocheilidae	Panchax Minnow	*Aplocheilus panchax* (Hamilton 1822)	Kanpona	LC	LC	+	+	+	+
Adrianichthyidae	Estuarine Rice Fish	*Oryzias melastigma* (McClelland, 1839)	Kanpona	LC	LC	+	+	+	+
Mastacembelidae	One-stripe Spiny Eel	*Macrognathus aral* (Bloch & Schneider, 1801)	Tara Baim	LC	DD	+	+	+	+
	Stripped Spiny Eel	*M. pancalus* Hamilton, 1822	Guchi Baim	LC	LC	+	+	+	+
	Spotted Spiny Eel	*M. aculeatus* (Bloch, 1786)	Tara Baim	NE	NT	+	+	+	+
	Tiretrack Spiny Eel	*Mastacembelus armatus* (Lacepède, 1800)	Sal Baim	NE	EN	+	+	+	+
Ambassidae	Elongated Glass Perchlet	*Chanda nama* Hamilton, 1822	Chanda	LC	LC	+	+	+	+
	Indian Glossy Fish	*Parambassis ranga* (Hamilton, 1822)	Ranga Chanda	LC	LC	+	+	+	+
	Indian Glossy Fish	*P. baculis* (Hamilton, 1822)	Kata Chanda	LC	NT	+	+	+	+
	Highfin Glassy Perchlet	*P. lala* (Hamilton, 1822)	Lal Chanda	NE	LC	+	+	+	+
Nandidae	Gangetic Leaffish	*Nandus nandus* (Hamilton, 1822)	Veda	LC	NT	+	-	+	+
Gobiidae	Tank Gobi	*Glossogobius giuris* (Hamilton, 1822)	Baila	LC	LC	+	+	+	+
Osphronemidae	Banded Gourami	*Trichogaster fasciata* Bloch & Schneider, 1801	Kholisha	LC	LC	+	+	+	+
	Dwarf Gourami	*Trichogaster lalius* (Hamilton, 1822)	Lal Khailsha	LC	LC	+	+	+	+
Anabantidae	Climbing Perch	*Anabas testudineus* (Bloch, 1792)	Koi	DD	LC	+	+	+	+
Channidae	Great Snakehead	*Channa marulius* (Hamilton, 1822)	Gajar	LC	EN	+	+	+	+
	Spotted Snakehead	*C. punctatus* (Bloch, 1793)	Taki	LC	LC	+	+	+	+
	Snakehead Murrel	*C. striata* (Bloch, 1793)	Shol	LC	LC	+	+	+	+
	Walking Snakehead	*C. gachua* (Hamilton, 1822)	Cheng	LC	LC	+	+	+	+
Tetraodontidae	Ocellated Pufferfish	*Leiodon cutcutia* (Hamilton, 1822)	Tepa	LC	LC	+	+	+	+
Clupeidae	Ganges River Spral	*Corica soborna* Hamilton, 1822	Kachki	LC	LC	+	+	+	+
Notopteridae	Clown Knife Fish	*Chitala chitala* (Hamilton, 1822)	Chital	NT	EN	+	+	+	+
	Bronge Featherback	*Notopterus notopterus* (Pallas, 1769)	Foli	LC	VU	+	+	+	+
Engraulidae	Gangetic Hairfin Anchovy	*Setipinna phasa* (Hamilton, 1822)	Faisa	LC	LC	+	+	+	+

Table 2. Exotic fish species found in Punarbhaba, Dhepa, and Atrai rivers in northwestern Bangladesh from 2009 to 2016 ('+' indicates presence and '-'indicates absence of species).

Family	Common name	Scientific name	Local name	Presence/ absence in rivers and sanctuary			
				Punarbhaba	Dhepa	Atrai	Sanctuary
Cyprinidae	Common Carp	*Cyprinus carpio* Linnaeus, 1758	Carpu	+	+	+	+
	Bighead Carp	*Hypophthalmichthys nobilis* (Richardson, 1845)	Bighead	+	+	+	+
	Java Barb	*Barbonymus gonionotus* (Bleeker, 1849)	Thai Sarpunti	+	+	+	+
Xenocyprididae	Grass Carp	*Ctenopharyngodon Idella* (Valenciennes, 1844)	Grass Carp	+	+	+	+
	Silver Carp	*Hypophthalmichthys molitrix* (Valenciennes, 1844)	Silver Carp	+	+	+	+
	Black Carp	*Mylopharyngodon piceus* (Richardson, 1846)	Black Carp	+	-	+	-
Loricariidae	Suckermouth Catfish	*Hypostomus Plecostomus* (Linnaeus, 1758)	Choshok Machh	+	-	-	-
Clariidae	African Catfish	*Clarias gariepinus* (Burchell, 1822)	African Magur	-	-	+	-
Chichlidae	Mozambique Tilapia	*Oreochromis mossambicus* (Peters, 1852)	Tilapia	+	+	+	+
Pangasiidae	Striped Catfish	*Pangasianodon hypophthalmus* (Sauvage, 1878)	Thai Pungus	+	-	-	-

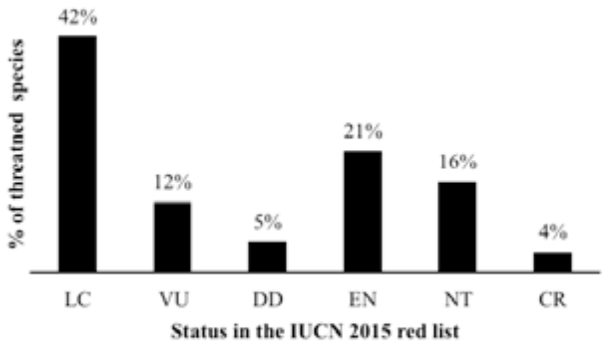

Figure 3. Threatened fish species recorded in Punarbhaba, Dhepa, and Atrai rivers of northwestern Bangladesh from 2009 to 2016 (CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern, DD = Data Deficient).

none of these was meant to be released into the wild. These exotic species might have, therefore, escaped from aquaculture ponds during heavy rains or flood. Currently, no information exists whether these exotic species have established breeding populations in the wild, and such studies need to be carried out in the future along with the development of management plans for their control and eradication.

Freshwater fish biodiversity in Bangladesh is under threat due to various anthropogenic and natural causes (Islam et al. 2017). This study indicated that Dhepa, Punarbhaba, and Atrai rivers are important habitats for 42 threatened species; therefore, sanctuaries were established to provide a safe refuge for the species, especially during the breeding period (Parvez et al. 2017). Other threats, such as water abstraction for agriculture, however, are threatening the ecosystem. Therefore, there is a need for a trade-off between managing rivers for biodiversity conservation and agricultural production. This study provides a scientific basis of fish biodiversity status which would be useful for policy-makers to set priorities for river management in Bangladesh.

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SHORT COMMUNICATION

NEW PLANT DISTRIBUTION RECORDS TO INDIAN STATES AND ADDITION TO THE FLORA OF MYANMAR

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Abstract: Plant genetic resource collection expedition across various parts of India and herbarium study of *Amaranthus* and *Luffa* genera at Botanical Survey of India (BSI), Kolkata and Coimbatore revealed the distribution of 18 plant taxa new to various Indian states/union territory, viz., Arunachal Pradesh (7), Andaman & Nicobar Islands (5), Jammu & Kashmir (3), Andhra Pradesh (2), Manipur (1), and Tamil Nadu (1). Out of these, 14 taxa have importance as wild relatives of 12 crop species. In addition, herbarium studies at the BSI, Kolkata revealed the natural distribution of a cucurbitaceous species – *Siraitia siamensis* in Myanmar, which remained unnoticed and unreported so far. Locality of herbarium/ germplasm collection, habitat and other field observations have been highlighted here.

Keywords: *Amaranthus*, Andaman & Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, crop wild relatives, Jammu & Kashmir, *Luffa*, Manipur, *Siraitia siamensis*, Tamil Nadu.

Reports on new distribution of economically important plant species not only help in updating the floristic database of the concerned region, but also help in augmenting unrepresented germplasm from such regions for conservation and sustainable utilization (Pradheep et al. 2011, 2018). Such reporting also helps in understanding their weedy potential, if any, so that prophylactic measures may be taken to avoid their fast spread to other areas. During field survey and collection of plant genetic resources, especially in various remote pockets of India for the past two years, authors came across the natural distribution of some plant taxa in different Indian states/union territory which were so far not reported. These taxa were studied critically in the

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natural habitat as well as in herbaria, supplemented with the study of online herbaria of London (BM), Edinburgh (E), Kew (K), Leiden (L), Paris (P) and Beijing (PE) including their type specimens. Apart from this, herbarium study of *Amaranthus* and *Luffa* genera carried out at BSI, Kolkata (CAL) and its southern regional centre, Coimbatore (MH) resulted in spotting of a few more taxa new to some Indian states.

Shortlisted taxa were thoroughly verified/ cross-checked with floristic and other key literature pertaining to the state/union territory and monographic/revisionary works pertaining to particular species/species group (Table 1; Naithani 1990; Karthikeyan et al. 2009; Pradheep et al. 2014b) besides verifying with all the available online sources. While herbarium vouchers are deposited in the National Herbarium of Cultivated Plants (NHCP) at ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi, germplasm collections (of relevant taxa) are being conserved in the form of seeds/live plants in National Genebank at ICAR-NBPGR, New Delhi.

Both field and herbaria studies revealed the natural distribution of 18 plant taxa (belonging to 16 genera, 12 families) so far not reported from various Indian states/ union territory are given in Table 1 (Fig. 1). This included seven taxa distributed in Arunachal Pradesh, five in Andaman & Nicobar Islands, three in Jammu & Kashmir, two in Andhra Pradesh, and one each from Manipur and Tamil Nadu. Out of 18 taxa, 14 were identified as wild relatives of 12 crop species. This includes close relatives/ progenitors of important crops such as *Vigna angularis* (Willd.) Ohwi & H.Ohashi var. *nipponensis* (Ohwi) Ohwi for adzuki bean, *Cucumis melo* L. subsp. *agrestis* (Naudin) Pangalo for muskmelon, *Solanum insanum* L. for brinjal, *Diospyros kaki* L. var. *silvestris* Makino for persimmon, *Momordica subangulata* Blume subsp. *subangulata* for teasel gourd, and *Fagopyrum tataricum* (L.) Gaertn. subsp. *potanini* Batalin for tartary buckwheat.

Addition to the flora of Myanmar

Herbarium study at CAL and cross-checking of available references – Kress et al. (2003), de Wilde & Duyfjes (2010) and efloras of China (http://efloras.org/flora_page.aspx?flora_id=2), further revealed the natural occurrence of a cucurbitaceous species, *Siraitia siamensis* (Craib) C. Jeffrey ex S.Q. Zhong & D. Fang, in Myanmar, which remained unnoticed so far.

Siraitia siamensis

(Craib) C. Jeffrey ex S.Q. Zhong & D. Fang, Guihaia 4(1): 23. 1984. W.J. de Wilde & Duyfjes, Blumea 51: 501. 2006; Fl. Thailand 9(4): 501. 2008; Fl. Males., Ser. 1, 19: 220. 2010. *Thladiantha siamensis* Craib, Bull. Misc. Inform. Kew No. 1: 7. 1914; Fl. Siam. 759. 1931. Cogn. in Engl., Pflanzenr. 66, 4.275.I: 47. 1916. Keraudren in Aubrév. & J.-F.Leroy, Fl. Cambodge, Laos & Vietnam 15 (34): 5. 1975. [Cucurbitaceae] (Image 3).

Type: *Kerr 1171*, Doi Suthep, Thailand (holotype K; isotype E 00433809).

Dioecious climber. Young twig yellow-brown pubescent, ± angular, c. 3mm diam. Tendrils short-pubescent, 2-branched, spiraling both below and above point of branching. Leaves: petiole 7–7.5 cm long, brown, hairy; blade simple, unlobed, ovate-cordate, 10–11 x c.8 cm, membranous, palmately 7-veined, adaxially sparsely hairy, abaxially dense brown tomentose, especially along nerves, margin almost entire, apex acuminate. Male inflorescence a simple raceme, 5–7 flowered, 12–13 cm long, flowers occur at the apex; bracts minute; peduncle c.8 cm long; all parts short brown-pubescent. Information on male and female flowers, fruits and seeds not known (from Myanmar).

Distribution: China (Guangxi, Yunnan), Indonesia (Java, Sumatra), Malaysia, Thailand, Vietnam; Myanmar (new report)

Herbarium examined: 3 (CAL), 30.iii.1930, La-pal Chaung, Tennasserim [Tanintharyi Region], Myanmar, 200ft, coll. K. Biswas.

Notes: In CAL, an anonymous annotation on the above herbarium sheet indicates "not present in India, *Luffa* sp. nov.". This herbarium record signifies the westward range extension of this medicinally important species, which was otherwise reported from south China, Indochina to West Malesia. In light of absence of fresh collections as well as reports, it appears to be a rare species in Myanmar. Present herbarium specimen showing flower bud initiation indicates that flowering would take place in April, which is in accordance with the literature.

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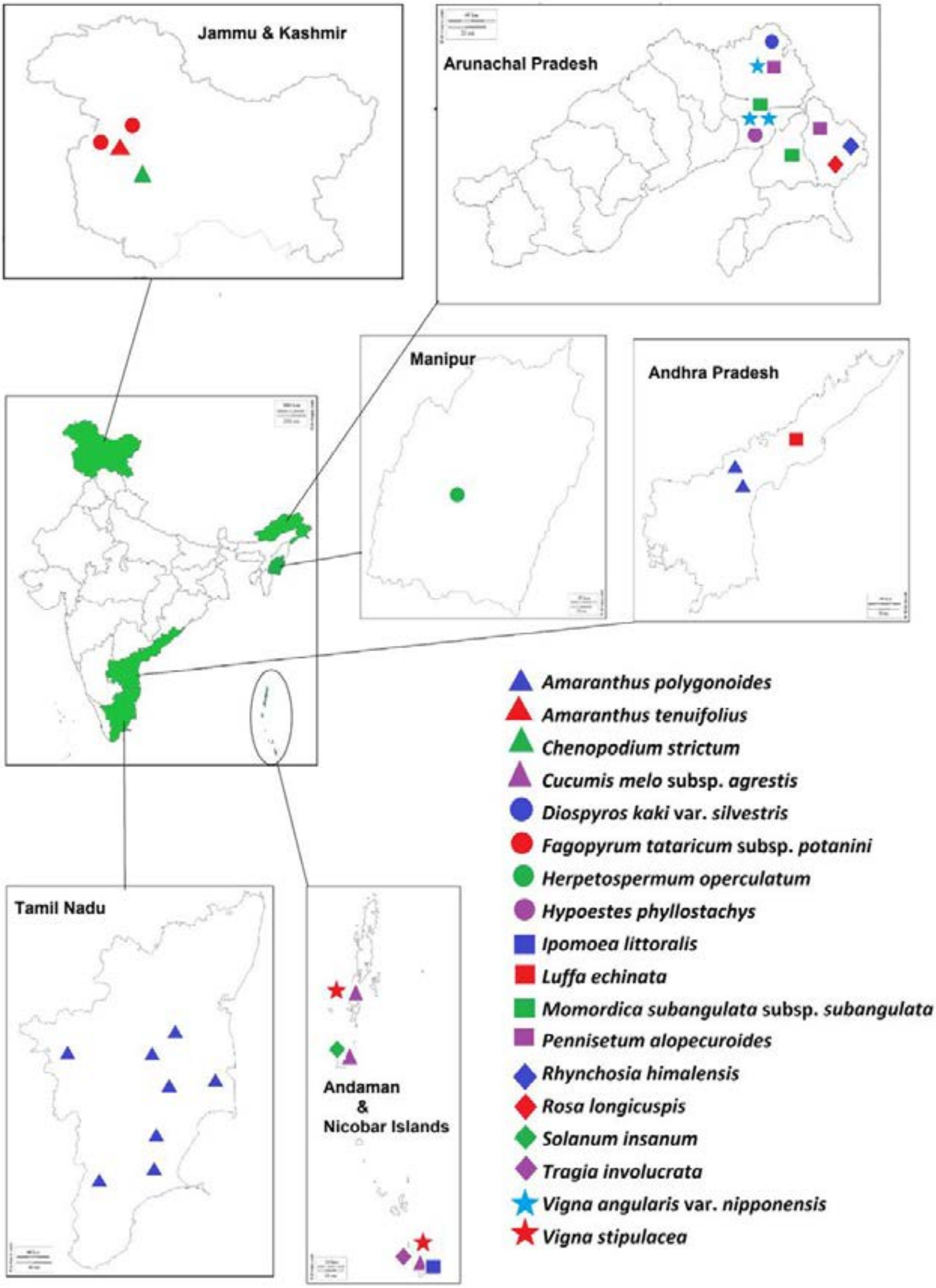

Figure 1. New distribution of plant species in various Indian states and union territory.

Table 1. Plant taxa new to Indian states and union territory.

	New to state/ UT	Taxon name [Family] and type details	Locality & herbarium/ germplasm collection details	Observations and remarks	Specific literature cross-checked
1	Andaman & Nicobar Islands	*Cucumis melo* L. subsp. *agrestis* (Naudin) Pangalo* [Cucurbitaceae] Type: *Naudin* s.n., cultivated from seeds from India (lectotype P00644216, designated by Kirkbride (1993)). [Image 1B]	Great Nicobar, Little Andaman, and South Andaman. JP/17-09 (live collection), 04.iii.2017, Campbell Bay, Great Nicobar; JPJ/18-50 (live collection), 19.i.2018, 3 km from Sastry Nagar to Galathea, Great Nicobar; JP/17-72 (live collection), 12.iii.2017, Hut Bay beach, Little Andaman; JPJ/18-12 (live collection), 13.i.2018, Guptapara, Port Blair, South Andaman.	Occasional weed in agricultural fields, roadsides, and other disturbed areas; flowering and fruiting throughout the year; distinguished from muskmelon (*C. melo* subsp. *melo*) by very shortly and densely puberulent ovary and small insipid fruits.	Chakravarty (1982); Dagar & Singh (1999); Diwakar & Pandey (2008); Renner & Pandey (2013); Yadav et al. (2014); Bheemalingappa et al. (2015); Naik et al. (2015); Rasingam (2015); Soyimchiten et al. (2015); Murugan et al. (2016); http://www.ildis.org/
		Ipomoea littoralis (L.) Blume* [Convolvulaceae] Type: *Blume 1710*, Java, Indonesia (holotype L0004195).	Great Nicobar. Also observed in Trinket Island. 2447 (NHCP23003), 06.iii.2017, Chingan, Great Nicobar, Coll. K. Pradheep & K. Joseph John.	Rare weed in coconut plantations and fields near coasts. This is the only relative of sweet potato reported from the Old World. It is characterized by mucronulate sepals and pink-purple corolla with a darker centre.	
		Solanum insanum L.* [Solanaceae] Type: *Herb. Linn.*, Surat, India (lectotype LINN 248.9, designated by Hepper & Jaeger 1985). [Image 1D]	Little Andaman. 2777 (NHCP23138; JP/17-71), 12.iii.2017, Hut Bay beach, Little Andaman, Coll. K. Pradheep & K. Joseph John.	Rare in coastal areas of Little Andaman. Progenitor of brinjal distinguished by prickly stem, more than one long-styled flower/ inflorescence, small fruits and green pulp.	
		Tragia involucrata L. [Euphorbiaceae] Type: Sri Lanka, Fl. Zeylanica 2: 12. p. 161. No. 340, Hermann herbarium (BM) (Chakrabarty & Balakrishnan 2006). [Image 1C]	Great Nicobar. 2764 (NHCP23125), 19.i.2018, Campbell Bay, Great Nicobar, Coll. K. Pradheep, K. Joseph John & I. Jaisankar.	Spreading fast in gravel heaps; this skin-irritant species is common in mainland of India.	
		Vigna stipulacea Kuntze* [Fabaceae] Type: Lamarck's collection (P00296830). [Image 1A]	Great Nicobar and South Andaman. 2459 (NHCP23008; JP/17-70), 09.iii.2017, Jetty Point, Campbell Bay, Great Nicobar, Coll. K. Pradheep & K. Joseph John; 2778 (NHCP23154), 14.i.2018, Brooksabad, Port Blair, South Andaman, Coll. K.Pradheep, K. Joseph John & I. Jaisankar .	Rare in disturbed areas; flowering and fruiting throughout the year. It is distinguished from related *V. trilobata* (L.) Verdc. by large ovate stipules, longer peduncle, brown-hairy mature pods and blackish seeds, and reports on the occurrence of the latter species in these islands is probably its misidentification.	
2	Andhra Pradesh	*Amaranthus polygonoides* L.* [Amaranthaceae] Type: Jamaica, [Icon] t. 92, f. 2 "*Blitum polygonoides viride seu ex viridi et albo variegatum polyanthos*" from Sloane (1707) (lectotype designated by Hendrickson 1999).	Guntur and Prakasam districts. 9639 (CAL), 13.vii.1961, Way to Siddhartha Hill, Nagarjuna Konda Valley, Guntur District, Coll. K. Thothathri; 194 (CAL), 01.x.1983, Mederametla, Prakasam district, Coll. R.K. Mohan; 289 (CAL), s.d., Kondaepi, Prakasam District, Coll. R.K. Mohan.	Herbarium label information indicates that this tropical American species is a common weed in waste and moist places.	Chakravarty (1982); Pullaiah & Chennaiah (1997); Pullaiah & Ali Moulali (1997); Pullaiah & Karuppusamy (2008); Renner & Pandey (2013); Yadav et al. (2014)
		Luffa echinata Roxb.* [Cucurbitaceae] Type: *Roxburgh 1694*, Coromandel, India, (lectotype K, designated by Jeffrey (1980)). [Image 6]	West Godavari District. 5296 (CAL), 10.xii.1910, Tummileru, (West) Godavari District, Coll. C.A. Barber.	Rare; although correctly identified in the herbarium specimen, it was overlooked by floras; nevertheless new collections are warranted. Relative of sponge and ridge gourd.	

	New to state/ UT	Taxon name [Family] and type details	Locality & herbarium/ germplasm collection details	Observations and remarks	Specific literature cross-checked
3	Arunachal Pradesh	*Diospyros kaki* L. var. *silvestris* Makino* [Ebenaceae] Type: Untraceable. [Image 2D]	Upper Dibang Valley District. 2734 (NHCP23041), 31.x.2017, Acheso, Angrim Valley, Upper Dibang Valley District, Coll. K. Pradheep, R.S. Rathi & G.D. Harish.	Although this botanical variety was not mentioned in Indian literature, this wild form (reported as *D. kaki*) of persimmon with smaller fruits was mentioned in Flora of Assam by Kanjilal et al. (1938). Associated with *Maclura cochinchinensis* (Lour.) Corner, *Rosa* sp., *Holboellia latifolia* Wall., etc. from 1100–1300 m.	Chakravarty (1982); Ghora & Panigrahi (1995); Hajra et al. (1996); Shukla (1996); Giri et al. (2008); Chowdhery et al. (2009); Renner & Pandey (2013), Yadav et al. (2014), Soyimchiten et al. (2015); Dash & Singh (2017); http://www.ildis.org/
		Hypoestes phyllostachya Baker [Acanthaceae] Type: *R. Baron 4907*, Madagascar (syntype P00089480).	Lower Dibang Valley District. 2698 (NHCP23039), 27.x.2017, Simari, Lower Dibang Valley District, 250m, Coll. K. Pradheep, R.S. Rathi & G.D. Harish.	This species, native to Madagascar, is naturalized in lower areas of eastern parts of the state; has foliage ornamental value due to leaves heavily-spotted pink or white.	
		Momordica subangulata Blume subsp. *subangulata** [Cucurbitaceae] Type: *Blume 769*, Java, Indonesia (lectotype L0001618, designated by De Wilde & Duyfjes (2002); isotypes L0001619 and L0001620). [Image 2A]	Lohit and Lower Dibang Valley districts. 2389 (NHCP22858), 17.x.2016, 15km before Salangan from Parasuram Khund, Lohit District, 1250m, Coll. K. Pradheep, G.D. Harish & K. Naveen; 2690 (NHCP23038), 28.x.2017, 5 km before Tewari Gaon from Roing, Lower Dibang Valley District, 1300m, Coll. K. Pradheep, R.S. Rathi & G.D. Harish.	Rare in open forests along with *Musa* spp., between 1000–1300 m; characterized by slender habit, long-peduncle and smaller and irregularly-ribbed fruit; valuable genetic resource for teasel gourd improvement.	
		Pennisetum alopecuroides (L.) Spreng.* [Poaceae] Type: *Herb. Linn*. (lectotype LINN 80.1, designated by Veldkamp (2000)). [Image 2B]	Anjaw and Upper Dibang Valley districts. 2397 (NHCP22859), 19.x.2016, Metengliang, Anjaw district, 1200m, Coll. K. Pradheep, G.D. Harish & K. Naveen; 2741 (NHCP23042; RPH-58), 30.x.2017, Etalin, Punli, Upper Dibang Valley District, 1350m, Coll. K. Pradheep, R.S. Rathi & G.D. Harish.	A striking perennial tussock-forming species, native to east and southeast Asia, Australia and Pacific Islands; gregarious in open disturbed areas, field margins and roadsides from 1200–1500 m. It is of value as forage cum ornamental.	
		Rhynchosia himalensis Benth. ex Baker [Fabaceae] Type: *T. Thomson* s.n., Himal. Bor. Occ. Regio trop., 3000–5000 ft, (M0240753). [Image 2C]	Anjaw District. 23856 (NHCP22856; IC621881), 22.x.2016, Badakandun, Kibithu, Anjaw District, Coll. K. Pradheep, G.D. Harish & K. Naveen.	Rare along hill slopes, this species is characterized by circular-rhomboid terminal leaflet with acuminate apex and loose flowers in inflorescence; found between 1300–1400 m.	
		Rosa longicuspis Bertol.* [Rosaceae] Type: *J.D. Hooker & T. Thomson* s.n., Khasia, 2–5000 ft., India (holotype K000730903, isotype P01819332). [Image 2F]	Anjaw District. 2356 (NHCP22846), 24.x.2016, 2 km from Hawai to Marbo, Anjaw District, 1650m, Coll. K. Pradheep, G.D. Harish & K. Naveen.	Occasional in mixed forests between 1200–1700 m. Close to the Himalayan musk rose, *R. brunonii* Lindl., but differing in glabrous, leathery more acuminate leaflets and fewer-flowered inflorescence. Dash & Singh (2017) mentioned as doubtful species in Kurung Kumey District of this state.	
		Vigna angularis (Willd.) Ohwi & H.Ohashi var. *nipponensis* (Ohwi) Ohwi *[Fabaceae] Type: *J. Ohwi 9069*, Hondo, Kyoto, Japan, 12.ix.1936 (isotype P02943396). [Image 2E]	Lower & Upper Dibang Valley districts. 2662 (NHCP23034), 28.x.2017, 10 km after Tiwari Gaon to Hunli, Lower Dibang Valley District, 1720m, Coll. K. Pradheep, R.S. Rathi & G.D. Harish; 2682 (NHCP23036), 27.x.2017, Kebali, Lower Dibang Valley District, 750m, Coll. K. Pradheep, R.S. Rathi & G.D. Harish; 2654 (NHCP23032; RPH-51), 29.x.2017, 10 km after Arali to Etalin, Upper Dibang Valley District, Coll. K. Pradheep, R.S. Rathi & G.D. Harish.	Occasional in partially disturbed habitats along roadside thickets between 600–1800 m; considered as the progenitor of adzuki bean, differing from it with respect to traits associated with domestication such as less seed number, small seed size and shattering nature of pod.	

	New to state/ UT	Taxon name [Family] and type details	Locality & herbarium/ germplasm collection details	Observations and remarks	Specific literature cross-checked
4	Jammu & Kashmir	*Amaranthus tenuifolius* Willd.* [Amaranthaceae] Type: *V.V. Jacquemont 1152*, Indes Orientales, (isotype (of *Mengea tenuifolia* Moq.) (P04021731)).	Baramulla District. 460 (CAL), vii.1905, Sumbal, [Baramulla District], Kashmir, 5000ft, Coll. A. Meebold.	Related to *A. graecizans* L., but distinguished from linear-oblong leaves, 2-tepals and 2-stamens; new collections warranted.	Kaul (1986); Paul (2012); Shrivastava & Shukla (2015)
		Chenopodium strictum Roth* [Chenopodiaceae] Type: *Heyne*, India oriental, *'Innominatum erat in Collectione spectatissima, qua me ditavit Clariss* ', Nov. Pl. Sp., 180. 1821. [Image 1E]	Budgam District. 2535 (NHCP23024; SHEIKH/KP/SR-682), 08.ix.2017, Chadoora, Hanjura, Budgam District, Coll. K. Pradheep & Sheikh M. Sultan.	Efloras of Pakistan (http://efloras.org/florataxon.aspx?flora_id=5&taxon_id=200006825) mentioned occurrence of this species in India, without further details; occasional along roadsides; also found in Beerwah area; related to chenopod (*Chenopodium album*) and differing from it by dark olive-green leaves, dense spike-like inflorescence and small, ovate seeds.	
		Fagopyrum tataricum (L.) Gaertn. subsp. *potanini* Batalin* [Polygonaceae] Type: untraceable [Image 1F]	Bandipore and Kupwara districts. 2542 (NHCP23105; IC625052), 13.ix.2017, Izmarg, Gurez Valley, Bandipore District, Coll. K. Pradheep & Sheikh M. Sultan; 2595 (NHCP23106), 14.ix.2017, Nacha, Sadhna Pass, Kupwara District, 2450m, Coll. K. Pradheep & Sheikh M. Sultan.	Seeds are characterized by crenate margin. Spontaneously comes up in cultivated fields and farm areas from 2000–3000 m. Though mentioned to occur in northern Kashmir (Ohnishi 1994), this progenitor of tartary buckwheat remained overlooked in Indian literature.	
5	Manipur	*Herpetospermum operculatum* K.Pradheep, A.Pandey, K.C.Bhatt & E.R.Nayar [Cucurbitaceae] Type: *K. Pradheep 1449*, Sadam, South Sikkim, India, (holotype CAL; isotypes NHCP, DD). [Image 4]	Bishnupur District. 6361 (CAL183461), ix.1907, Laimatak [Bishnupur dt.], 4000ft, Coll. A. Meebold.	This recently described species is so far known from Nagaland, Sikkim and Arunachal Pradesh in India. This herbarium specimen was originally kept as *H. caudigerum* Wall. (=*H. pedunculosum* (Ser.) Baill.).	Pradheep et al. (2014a)
6	Tamil Nadu	*Amaranthus polygonoides* L.* [Amaranthaceae] [Image 5]	Coimbatore, Pudukkottai, Ramanathapuram, Thanjavur, Tiruchirappalli and Virudhunagar districts. 8545 (CAL), 28.vii.1959, RS Puram, Coimbatore District, 467m, Coll. K. Subramanyam; 512 (CAL), 22.vi.1973, Maruthamalai, Coimbatore District, Coll. R.N. Kayal & G.N. Tribedi; 213 (MH141638), 13.x.1984, Pudukkottai, Pudukkottai District, 110m, Coll. C. Arulappan; 1060 (MH144151), 21.xii.1986, Valantharavai, Ramanathapuram District, 50m, Coll. V. Balasubramanian; 2364 (MH144625), 30.xii.1989, Sikkal, Ramanathapuram District, ±40m, Coll. V. Balasubramanian; 941 (CAL), 09.i.1989, Manakkal, Thanjavur District, 50m, Coll. S. Ragupathy; RHT 11940 (CAL), 17.ii.1978, Kilikkoodu, near Grand Anicut, Tiruchirappalli District, Coll. Rajendran & Diraviam; 61471 (CAL), 26.ii.1979, Sanjeevimalai, Rajapalayam, Virudhunagar District, ±275m, Coll. N.C. Nair.	Common in low-lying moist grounds. Mostly misidentified in herbaria as *A. roxburghianus* Nevski or *A. mangostanus* L. Easily distinguished from the above species of flowers with 5 linear-spathulate tapes which are connate at base.	Henry et al. (1987); Matthew (1991); http://www.tnenvis.nic.in/PDF/floralchecklist.xls

*Wild relative of crop species

Image 1. New distribution of plant species in Indian states/union territory: A - *Vigna stipulacea* in South Andaman (inset: flower & fruit) | B - *Cucumis melo* subsp. *agrestis* in Great Nicobar | C - *Tragia involucrata* in Great Nicobar | D - *Solanum insanum* in Little Andaman (inset: fruit) | E - *Chenopodium strictum* in Jammu & Kashmir | F - *Fagopyrum tataricum* subsp. *potanini* in Jammu & Kashmir. © K. Pradheep.

Image 2. New distribution of plant species in Arunachal Pradesh: A - *Momordica subangulata* subsp. *subangulata* (inset: opened-up dead-ripe fruit) | B - *Pennisetum alopecuroides* | C - *Rhynchosia himalensis* | D - *Diospyros kaki* var. *silvestris* | E - *Vigna angularis* var. *nipponensis* | F - *Rosa longicuspis* (inset: fruits). © K. Pradheep.

Image 3. Herbarium of *Siraitia siamensis* from Myanmar at CAL [image by Director, BSI, Kolkata].

Image 4. Herbarium of *Herpetospermum operculatum* from Manipur at CAL [image by Director, BSI, Kolkata].

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Image 5. Herbarium of *Amaranthus polygonoides* from Tamil Nadu at MH [credit: Director, BSI, Kolkata].

Image 6. Herbarium of *Luffa echinata* from Andhra Pradesh at MH [credit: Director, BSI, Kolkata].

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Sighting of Arunachal Macaque *Macaca munzala* Sinha et al., 2005 (Mammalia: Primates: Cercopithecidae) in Sakteng Wildlife Sanctuary, Bhutan

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Arunachal Macaque *Macaca munzala* Sinha et al., 2005, described from the Indian state of Arunachal Pradesh, is amongst the several discoveries from the region during second millennia (Mishra et al. 2004; Sinha et al. 2005).

Morphologically, it is distinguished from rest of the *sinica* species group with predominantly dark crown patch, characteristic facial marks on the temple and forehead with pale collar hair around the neck and distinctive relative short tail (Sinha et al. 2005). Arunachal Macaque is mostly terrestrial and occurs at an altitudinal range of 2000–3500 m (Sinha et al. 2005). Species is relatively tolerant to anthropogenic activities and dwells in an array of habitats, including degraded broadleaf forest, degraded open scrub forest, agricultural areas, and undisturbed oak and conifer forest (Sinha et al. 2005). In India, species was reported to occur in western Arunachal Pradesh with distribution mostly restricted in Tawang and West Kameng districts of the state (Sinha et al. 2005, 2006; Kumar et al. 2008)

Six species of non-human primates are known to exist in Bhutan. These include Slow Loris *Nycticebus bengalensis*; Assamese Macaque *Macaca assamensis*; Rhesus Macaque *Macaca mulatta*; Himalayan Langur *Semnopithecus schistaceus*; Golden Langur *Trachypithecus geei* and Capped Langur *Trachypithecus pileatus* (Wangchuk et al. 2004; Choudhury 2008). Considering the proximity and continuity of forest cover along borders of Eastern Bhutan and Arunachal Pradesh, Arunachal Macaque is also likely to occur in Bhutan (Sinha et al. 2006; Kumar et al. 2008). Although sighting of Arunachal Macaque in Trashi Yangtse and Trashigang districts at an elevation of 900m was reported (Choudhury 2008), its presence and distribution in Sakteng Wildlife Sanctuary (SWS) which is connected to Arunachal Pradesh remains unknown (SWS 2016).

According to the IUCN Red List of Threatened Species, Arunachal Macaque is listed under the endangered category (Kumar et al. 2008)

To explore the possible occurrence of the species in SWS, we conducted surveys in the month of December 2016 and January 2017. Sakteng and Joenkhar ranges under SWS were classified into different vegetation types based on Bhutan land use and land cover 2010 data. Further, probable sighting sites for any kind of primates within the study area were gathered from the local inhabitants who are transhumant by profession and have sighted the primates in recent past during their stay in the wild while herding livestock. Survey was conducted based on direct observation along the sighting sites suggested by the local people and in randomly selected suitable vegetation/habitat types.

During the fourteen day survey, a troop of macaques

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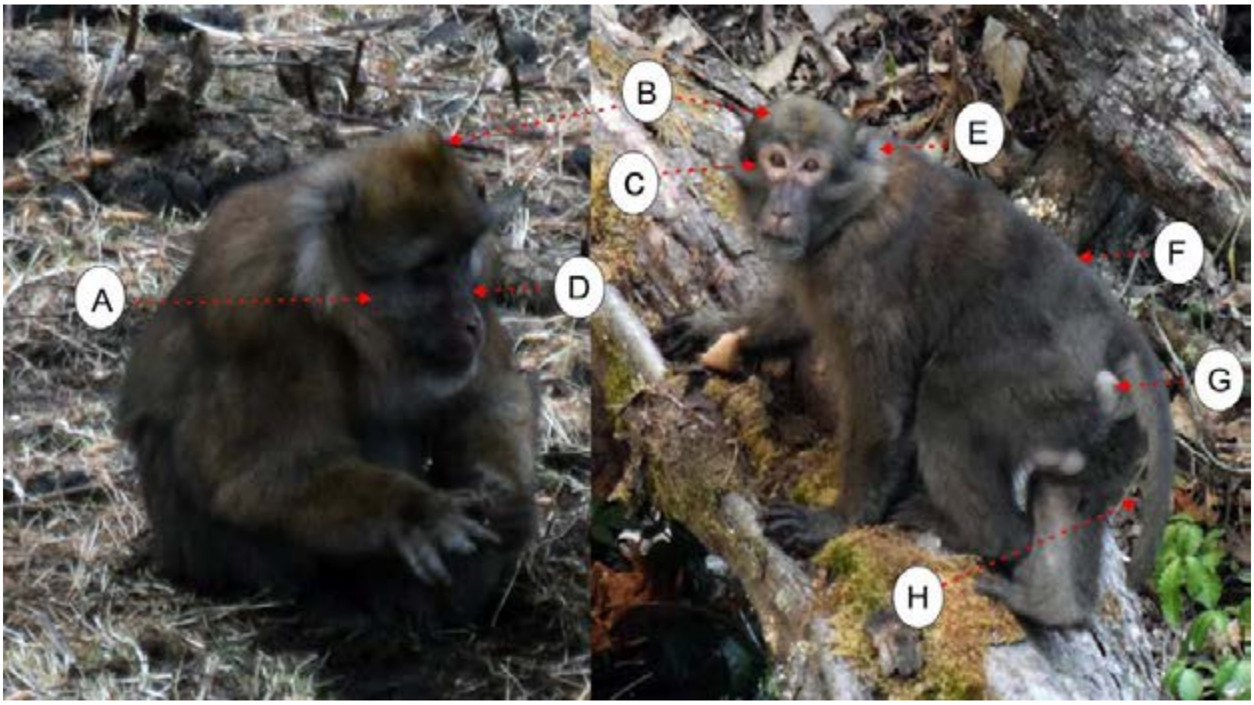

Image 1. Features based on which the species was confirmed: A - Prognathous head | B - Prominent pale-yellow patch | C - Pale skin around the eye | D - Dark brown facial skin | E - Dorsal ring of lighter colored hair between the head and trunk | F - Dark brown to chocolate color coat | G - White in buttock area as suggested by Anwaruddin Choudhury, 2008 | H - Distinctive in relative tail length, which is intermediate between those of Tibetan and Western Assamese Macaques as suggested by Sinha et al. 2005. © Authors.

Figure 1. *Macaca munzla* sighting site in Sakteng Wildlife Sanctuary and other regions.

was sighted at Joenkhar-teng (altitude 1723m) in the mixed broadleaved forest near the Gamri River (Fig. 1; Image 1).

We looked for distinct characteristics of the species in the photo and found its resemblance to Arunachal Macaque. For further confirmation we consulted numerous literatures in primates of Bhutan and nearby region (Sinha 2004; Sinha et al. 2005, 2006; Wangchuk et al. 2004; Choudhury 2008; Kumar et al. 2008; Biswas et al. 2011; Chetry et al. 2015; Li et al. 2015) and also sought an identification from Dr Anwaruddin Choudhury and other experts by sending the photographs with other necessary morphological description of the species.

On the account of our observation, photographs and expert's comment, we conclude that the species recorded at Joenkhar-teng under Joenkhar range is an Arunachal Macaque *Macaca munzala* Sinha et al., 2005. Local people call it as a 'Naka-Zala' (Brami: Forest Monkey) and Borang-Zala (Sharchokpa: Forest Monkey)

Including the sighting of *Macaca munzala*, SWS is home to 38 species of mammals and hope that addition of the species enhances the prospect of biodiversity conservation and gives more importance to further field research and habitat management.

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Rediscovery of an endemic Indian moth *Gurna indica* (Moore, 1879) (Lepidoptera: Erebidae: Arctiinae) after 125 years

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The genus *Gurna* was erected as a monotypic genus by Swinhoe in 1892 for *Dysauxes indica* from 'Bombay'. Hampson (1894) treated *Gurna* as a separate genus and described it in detail. Later, Hampson (1900) synonymized *Gurna* with the genus *Miltochrista* Hübner, [1819] where it remained until the 20th Century. Again, Holloway (2001) and Volynkin (2016a) considered *Gurna* a separate genus. Recently, Volynkin (2016b) restored it as a genus and revised its status based on the type species. *Gurna indica* is the only known species from the genus. The literature published on moths covering Maharashtra (Shubhalaxmi et al. 2011; Gurule & Nikam 2013) and India (Shubhalaxmi 2018) did not record *G. indica*. Till this study, no fresh specimen of this species was collected. Hence, this finding is a rediscovery of this moth after a long gap of nearly 125 years. Hampson (1894) mentioned the distribution of this species as 'Bombay' and Watson collected three males from 'Belgaum' in 1896 (Hampson 1900). This is a genus endemic to India and belongs to the *Miltochrista-Asura* generic complex (Volynkin 2016b).

One female specimen was collected by the second author from, Pune District, Maharashtra, India, using a light trap. The collected specimen was killed with ethyl acetate vapours. Further, it was relaxed, pinned, and dry preserved in the laboratory. The identification of the specimen was done with the help of Hampson (1894) and Volynkin (2016b). The specimen was studied under a Leica EZ 4 E stereozoom microscope with photographic facility. The images were stacked using Combine ZP software and then processed with Adobe Photoshop CS Version 8. To describe the morphological and genitalia features, terminology as per Hampson (1894) and Volynkin (2016b) was used. To study the external female genitalia, the methodology mentioned by Robinson (1976) was followed. The distribution records were verified from literature (Swinhoe 1892; Hampson 1894, 1900; Strand 1922; Singh et al. 2014; Volynkin 2016b). The identified specimen was duly registered and deposited in the National Zoological Collection, Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI–WRC). The detailed collection locality is given under material examined and also shown in Fig. 1. The map of the collection locality was prepared using the open, free access QGIS software.

Superfamily: Noctuoidea Latreille, 1809
Family: Erebidae Leach, [1815]
Subfamily: Arctiinae (Leach, 1815)
Tribe: Lithosiini Billberg, 1820
Subtribe: Nudariina Borner, 1920
Genus: *Gurna* Swinhoe, 1892

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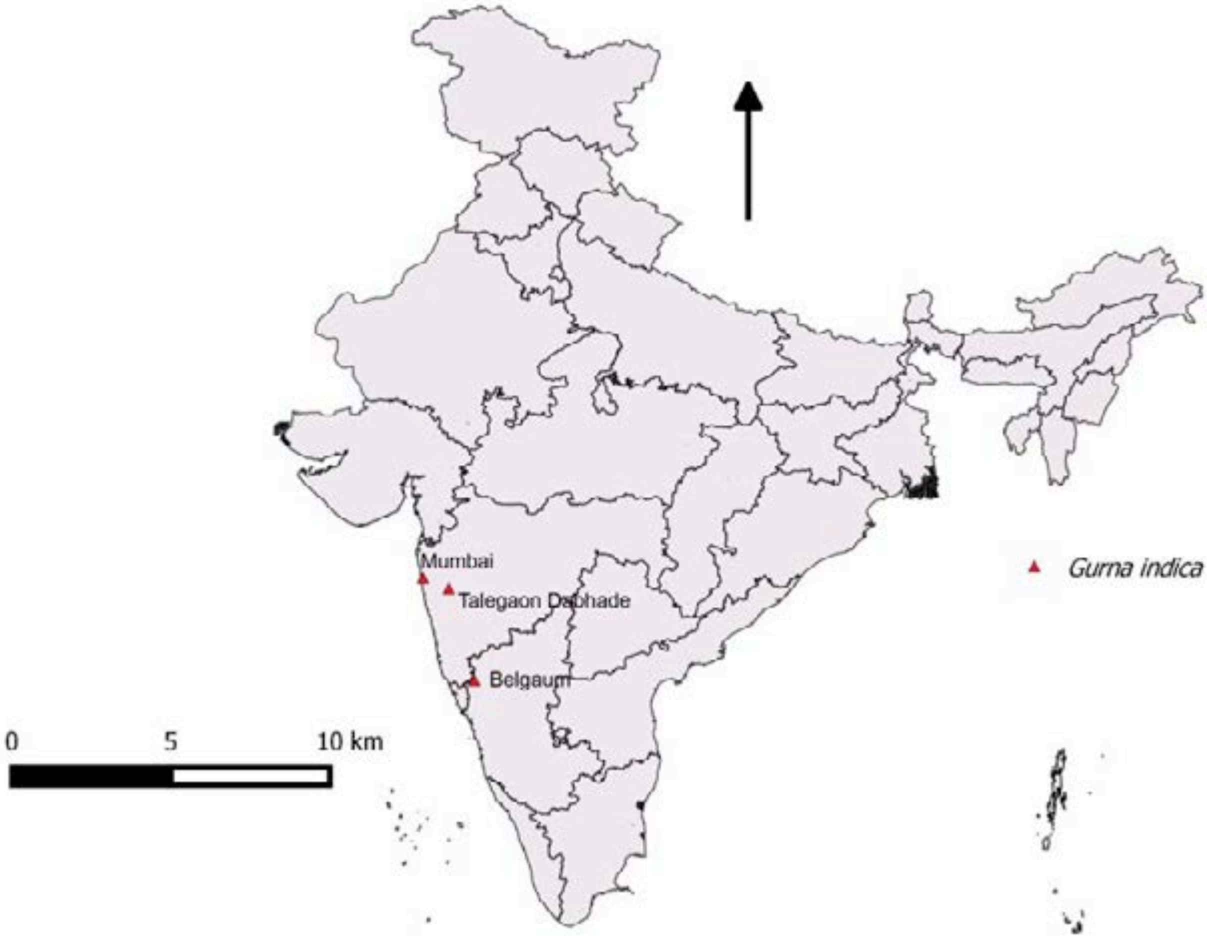

Figure 1. New (Talegaon Dabhade) and old (Mumbai & Belgaum) collection localities of *Gurna indica* in India.

Gurna indica (Moore, 1879)

Dysauxes indica Moore, 1879, *P. Z. S.*: 390.

Gurna indica Hampson, 1894, *Fauna Brit. India*, 2: 105.

Miltochrista indica Hampson, 1900, *Catalog. Lepid. Phalaenae Brit. Mus.,* 2: 474.

Gurina indica Volynkin, 2016b, *Biolog. Bull. Bogdan Chmeln. Melitopol Pedagog. Uni.,* 6 (3): 290–294.

Type locality: Bombay (=Bombay Presidency; probably not present-day Mumbai).

Material examined: ZSI–WRC–L–1825, 1ex., female, 30.ix.2018, Talegaon Dabhade, Pune District, Maharashtra, India, 18.73°N & 73.68°E, 617m, coll. N. Upadhyay.

Description: Female (Image 1A,B): body dark olive-brown; antennae filiform; frons and patagia bright yellow, except at base; posterior half of tegulae bright yellow; extremity of abdomen yellow. Palpi very short, porrect. Forewing dark olive-brown, elongated, narrow, apex rounded; vein 4 and 5 from angle of cell; 6 from below upper angle; 7, 8, 9 stalked; a round bright yellow spot in end of cell extended till costa, similar spot but not rounded at base of inner margin. Hindwing bright yellow basally, with broader olive-brown band terminally; vein 4 and 5 from angle of cell; 6 and 7 stalked; 8 from after middle of cell. Terminal minute pairs of spurs in the middle and hind femora. The underside of both wings is exactly the same except that the spots of the forewings are less defined.

Forewing length: 30mm.

Female genitalia (Image 1C,D): corpus bursae globular, with small thorn-like structures, contains short, tubular signum; ductus bursae membranous, short; posterior and anterior apophyses are slender, longer, and pointed at apex; papilla analis with setae.

Known distribution: India (Maharashtra and Karnataka) (Swinhoe 1892; Hampson 1894, 1900; Strand 1922; Singh et al. 2014; Volynkin 2016b).

Image 1. *Gurna indica*: A - dorsal view of adult | B - ventral view of adult | C, D - female genitalia. Scale = 2mm for A & B, 0.5mm for C & D. © Aparna S. Kalawate.

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The Nepal Pipewort *Eriocaulon nepalense* var. *luzulifolium* (Commelinids: Poales: Eriocaulaceae): a new distribution record for southern India

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The genus *Eriocaulon* L. (Eriocaulaceae) is one of the diverse genera distributed in the tropical and sub-tropical regions of the world. Linnaeus (1753), while enumerating the genus *Eriocaulon*, recognised four species, of which three were from India. Ansari & Balakrishnan (1994) described 65 species from India and categorised them under 12 sections in their revision of Indian Eriocaulaceae. Ansari & Balakrishnan (2009) further revised the genus and reported 80 species from India. Since then more species have been described from southern India by subsequent floristic explorations (Yadav et al. 2008; Shimpale et al. 2009; Vivek et al. 2010; Nampy et al. 2011; Swapna et al. 2012; Rashmi & Krishnakumar 2014; Manudev et al. 2015; Sunil et al. 2015; Anto & Resma 2017; Darshetkar et al. 2017; Kumar et al. 2017; Manudev et al. 2017; Sunil et al. 2017).

During the floristic exploration in the Kollengode range of forests in Nemmara Forest Division of southern Western Ghats, we came across an interesting specimen of *Eriocaulon* growing in the Manpara region of Nelliyampathy Hills and was identified as *Eriocaulon nepalense* var. *luzulifolium* (Mart.) Praj. & J. Parn., hitherto unknown from any of the southern Indian states.

Eriocaulon nepalense* var. *luzulifolium

(Mart.) Praj. & J. Parn. in Kew Bull. 67: 664. 2012

Eriocaulon luzulifolium (sphalm.: luzulaefolium) Mart. in Wall., Pl. Asiat. Rar. 3: 28. 1832; Hook. f., Fl. Brit. India 6: 582. (1893). *Eriocaulon pumilio* Hook. f., Fl. Brit. India 6: 581. 1893; *Eriocaulon lepidum* T. Koyama, Philipp. J. Sci. 84: 371. 1956. *Eriocaulon papuanum* P. Royen, Nova Guinea, Bot. 10: 37. 1959. *Eriocaulon kathmanduense* Satake, Bull. Univ. Mus. Univ. Tokyo 2: 157. 1971. *Eriocaulon pseudonepalense* Satake, Acta Phytotax. Geobot. 26: 50. 1974.

Acaulescent herbs. Root stock conical, 2.5–3 cm × 0.81cm. Leaves rosulate, oblong-lanceolate, apiculate up to 9–12 cm × 0.8–1.5 cm, glabrous. Sheaths up to 6–7 cm long, glabrous, margin entire, limb apex split into 2 or 3 acute lobes. Peduncles 16–18 in number, erect upto 21–25 cm, 6-ribbed. Heads ovoid, 3mm × 5mm across, pale black or grey. Receptacle ovoid, pilose. Involucral bracts 1.5mm × 1.2mm, orbicular – obovate, lacerate, grey-coloured, glabrous. Floral bracts 2mm × 0.85mm, oblanceolate, acuminate, hoary towards tip, black. Male flowers: pedicel 0.5mm long, sepals obovate, connate into a spathe at the base, upper portion divided into three acute lobes, hoary towards tip, black. Petals 3, acuminate, minute. Anthers 6, globose, black. Female flowers: Pedicel 0.3–0.4 mm

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long. Sepals 3, 1.7mm long, free, similar, linear, acute, hoary towards apex, black. Petals 3, equal, hyaline, 1.5mm long, eglandulose, stipitate between sepals and petals. Ovary 0.3mm, sub-sessile, ovoid, style 0.2mm, stigma 0.3mm, 3 fid. Seeds ellipsoid, 0.5mm × 0.2mm, yellow, cells of seed coat transversely elongated, aligned in vertical rows, appendages 1–4 from the middle of transverse radial walls. Appendages setiform, retuse at the apex (Image 1).

Phenology: August–October.

Habitat: This plant was observed in waterlogged areas in evergreen forests.

Specimen examined: 1126 (ERRC), 177799 (MH), 25.ix.2015, India, Kerala, Palakkad District, Kollengode range, Manpara, 10.522^{0}N & 76.747^{0}E, 1275m, coll. Soumya & Maya (Image 2).

Distribution: Thailand, Nepal-Himalaya to southern China, New Guinea, Srilanka, India (Assam, Manpara (Nelliampathy Hills) of Kerala part of the Western Ghats).

Conservation status: Field explorations revealed that the plant taxon is rare in occurrence and only a single population with a small number of individuals inhabiting the Manpara region of Kollengode range forests was found. Analysing the global distribution informed that the plant taxa is observed to thrive in humid climatic conditions of higher altitudes above 1000m. The current status of the species is assigned to be Least Concern as per IUCN Version 2018-2 (IUCN 2018).

Additional specimens examined: Kew digital herbarium barcode ID: K000098620, K000098635 and K000098704.

Nomenclature notes: *Eriocaulon nepalense* Prescott ex Bong. and *Eriocaulon luzulifolium* Mart. were described as separate species in *Mém. Acad. Imp. Sci. St.-Pétersbourg, Sér. 6, Sci. Math.* (1830) and *Pl. Asiat. Rar.* (1832), respectively. Later on Prajaksood et al. (2012) proposed a new combination, *Eriocaulon nepalense* Prescott ex Bong. var. *luzulifolium* (Mart.) Praj. & J. Parn. comb. *et* stat. nov. The specific epithets *Eriocaulon luzulifolium* Mart., *Eriocaulon pumilio* Hook. f., *Eriocaulon lepidum* T. Koyama, *Eriocaulon papuanum* P. Royen, *Eriocaulon kathmanduense* Satake, *Eriocaulon pseudonepalense* Satake were treated as synonyms. It is also noted that, as per IPNI, *Eriocaulon nepalense* var. *luzulifolium* (Mart.) Praj. & J. Parn. is the correct name and *Eriocaulon luzulifolium* Mart. forms the basionym from which the name of variety *'luzulifolium'* was derived.

Taxonomic delineation from *Eriocaulon nepalense* Prescott ex Bong.: The specimen differs from the typical variety in having acute leaf apex, entire margin and more or less pilose receptacle. Root stock is elongated, stout and densely fibrous. Prajaksood et al. (2012) observed that the distribution of *Eriocaulon nepalense* var. *luzulifolium* is wider than the typical variety and the morphology of the taxon is influenced by growth conditions.

Taxonomic delineation of *Eriocaulon nepalense* var. *luzulifolium* from the other taxa recognised in the 'Flora of Presidency of Madras': The taxon *Eriocaulon nepalense* var. *luzulifolium* (Mart.) Praj. & J. Parn. has not been enlisted in the Flora of Presidency of Madras.

Table 1. Taxonomic delineation of *Eriocaulon nepalense* var. *luzulifolium* (Mart.) Praj. & J. Parn. from the other taxa recognized in the 'Flora of Presidency of Madras'.

Characters	**E. *nepalense* var. *luzulifolium* (Mart.) Praj. & J. Parn.**	**Taxa compared**
Habitat	Terrestrial waterlogged areas	*E. setaceum* L.—Aquatic plant in which stems remain submerged, and only the peduncles emerge out of water
Nature of sheath	The apex of sheath is split into 2 or 3 acute lobes.	*E. longicuspis* Hook. f. var. *polycephala* Fyson & *E. odoratum* Dalz.—The mouth of the sheath enclosing the leaves were distinctly oblique and closed
Number of peduncles	About 16-18 peduncles	*E. pectinatum* Ruhl. & *E. robustum* Steud.—Usually solitary peduncle
Number of ribs in peduncle	Six ribs	*E. quinquangulare* L., *E. collinum* Hook. f. & *E. conicum* Fischer—Five, Five-Eight and Five respectively.
Receptacle	Pilose	*E. melaleucum* Mart., *E. ritchieanum* Ruhl. & *E. truncatum* Ham., *E. sieboldianum* Sieb & Zucc—Glabrous
Involucral bracts and flowers	Involucral bracts were not longer than floral bracts	*E. dianae* Fyson, *E. dianae* var. *longibracteata* Fyson, *E. dianae* var. *richardiana* Fyson & *E. xeranthemum* Mart.—Involucral bracts were longer than floral bracts and flowers
Nature of involucral bract	Glabrous	*E. brownianum* Mart. var. *nilagirense, E. robusto-brownianum* Ruhl. & *E. lanceolatum* Miq.—Pilose
Colour of involucral bract	Grey	*E. margaretae* Fyson & *E. elenorae* Fyson—Hyaline
Number of sepals	Three	*E. cuspidatum* Dalz., *E. stellulatum* Koern., *E. sexangulare* L., *E. ensiforme* Fischer, *E. vanheurckii* Muell. Arg., *E. minutum* Hook. f., *E. thwaitesii* Koern. & *E. gamblei* Fischer—Two

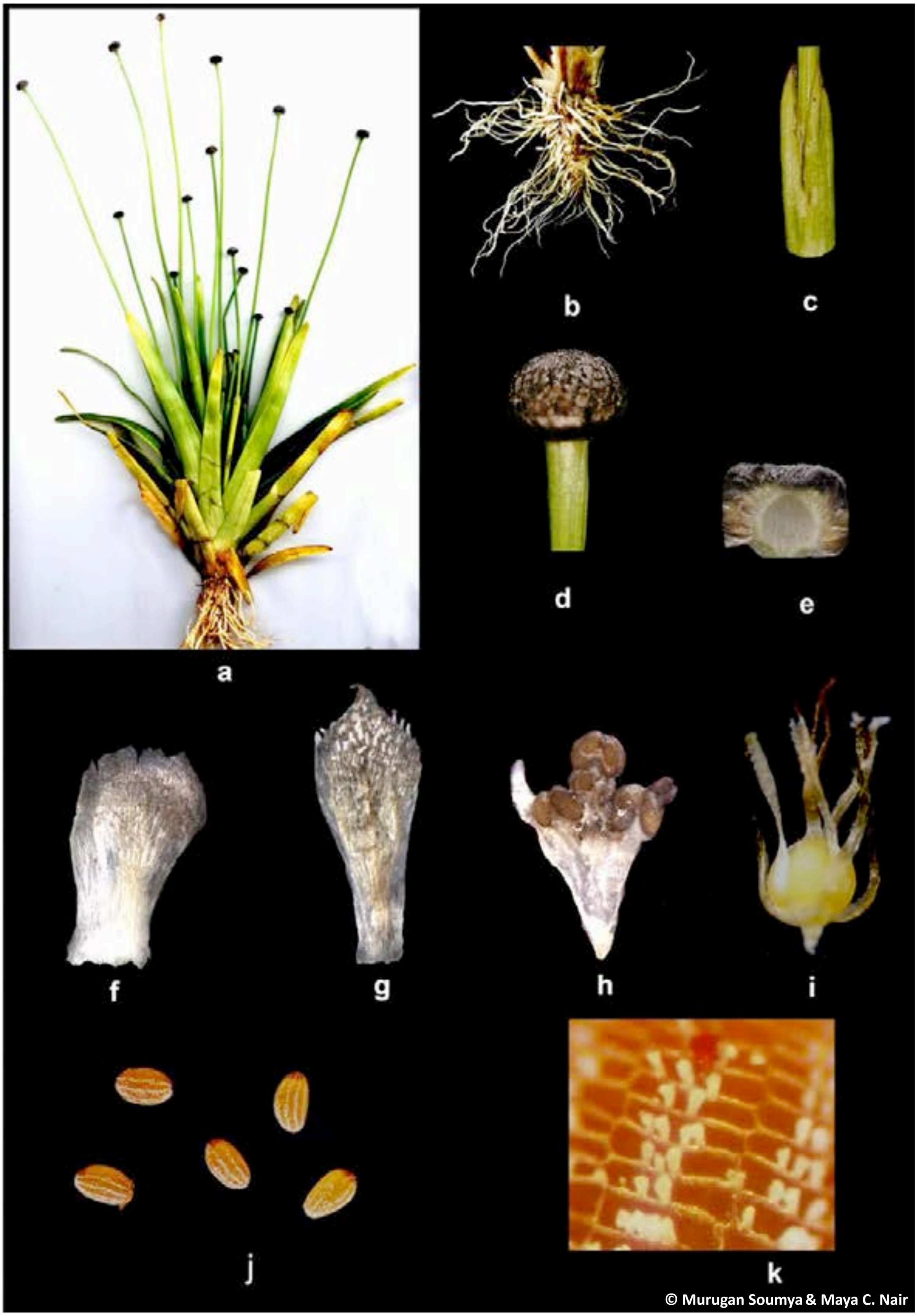

Image 1. ***Eriocaulon nepalense*** **var.** ***luzulifolium*** **(Mart.) Praj. & J. Parn.: a - habit | b - root stock | c - limb apex | d - head | e - head LS | f - involucral bract | g - floral bract | h - male flower | i - female flower | i - female flower | j - seed | k - seed surface enlarged showing appendage.**

The combination of characters such as presence of rootstock, split leaf sheath apex, 6-ribbed peduncle, 16–18 peduncles, pilose receptacle, grey coloured glabrous involucral bract, three male sepal lobes, presence of black anthers and seed coat surface with 1–4 appendages from the middle of transverse radial walls clearly demarcates this from the other allied taxa in the genus *Eriocaulon*. Table 1 summarizes the critical comparison of *Eriocaulon nepalense* var. *luzulifolium* with 29 taxa under the genus *Eriocaulon* (comprising 25 species and 4 varieties) enumerated in the Flora of Presidency of Madras (Gamble 1915–1936).

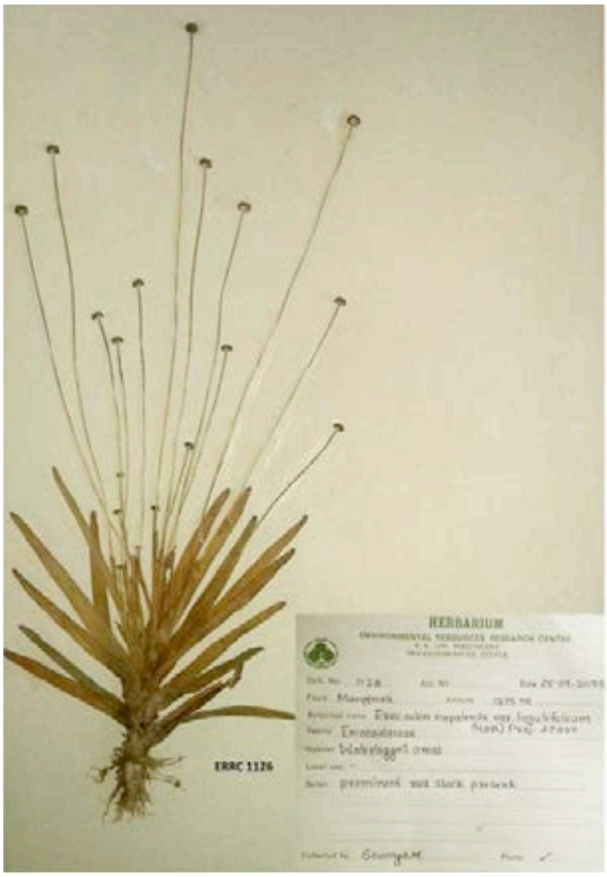

Image 2. Herbarium of *Eriocaulon nepalense* var. *luzulifolium* (Mart.) Praj. & J. Parn.

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