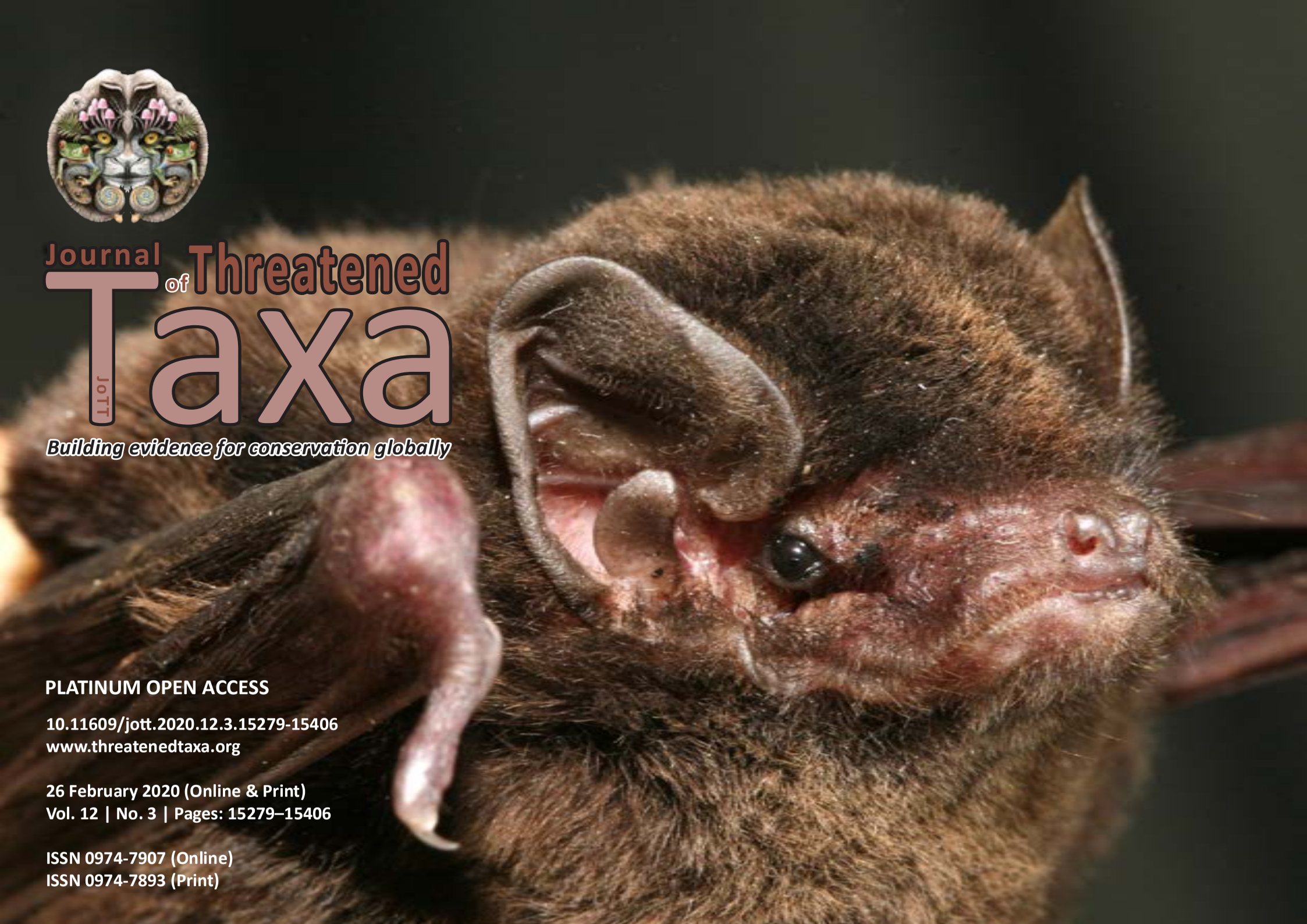

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Cover: A Western Bent-winged Bat *Miniopterus magnater* from Umlyngsha, Meghalaya. © M. Ruedi.

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REVIEW

Ramifications of reproductive diseases on the recovery of the Sumatran Rhinoceros *Dicerorhinus sumatrensis* (Mammalia: Perissodactyla: Rhinocerotidae)

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Abstract: The Sumatran Rhinoceros *Dicerorhinus sumatrensis* is on the edge of extinction. The decline of this species was initially attributed to poaching and habitat loss, but evidence presented here indicates that reproductive failure has also been a significant cause of loss, and continues to affect wild populations. Indonesia's remaining populations of Sumatran Rhino are small and scattered, with limited access to breeding opportunities with unrelated mates. This leaves them subject to inbreeding and isolation-induced infertility, linked to fertility problems analyzed here. Sumatran Rhino females in captivity showed high rates (>70%) of reproductive pathology and/or problems with conception, which has significantly hindered the breeding program. Technological advances enabling examination immediately after capture revealed similarly high rates and types of reproductive problems in individuals from wild populations. The last seven Sumatran Rhino females captured were from areas with small declining populations, and six had reproductive problems. Going forward, capturing similarly compromised animals will take up valuable space and resources needed for fertile animals. The high risk of infertility and difficulty of treating underlying conditions, coupled with the decreasing number of remaining animals, means that the success of efforts to build a viable captive population will depend upon utilizing fertile animals and applying assisted reproductive techniques. Decades of exhaustive in situ surveys have not provided information relevant to population management or to ascertaining the fertility status of individual animals. Thus the first priority should be the capture of individuals as new founders from areas with the highest likelihood of containing fertile rhinos, indicated by recent camera trap photos of mothers with offspring. In Sumatra these areas include Way Kambas and parts of the Leuser ecosystem.

Keywords: Extinction, isolation-induced infertility, pathology, reproduction.

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INTRODUCTION

The global population of Sumatran Rhinoceros *Dicerorhinus sumatrensis* was estimated at less than 100 individuals at the Sumatran Rhino Crisis Summit of 2013. For decades, the persistent decline has been attributed to uncontrolled poaching and habitat loss. Evidence presented here, however, indicates that reproductive failure (previously only associated with captivity) is an important factor in the continued decline of this species. The prevalence of reproductive problems across time and landscapes indicate a need to understand the scope and nature of this failure for successful recovery.

Between 1984 and 1995, a total of 41 Sumatran Rhinos were captured in Indonesia (Sumatra) and Malaysia (Peninsular and Sabah) (Rookmaaker 1998). The majority of males and females were placed in breeding facilities in each range country; three were moved to the United Kingdom and seven to the United States. At that time, the husbandry of this species was poorly understood and insufficient knowledge about diet, habitat, social structure, mating behavior, and reproduction hampered breeding efforts. Introductions of males and females often led to violent responses. These husbandry gaps resulted in significant losses in the initial captive population. Improvements in diet and behavioral management addressed some of these challenges, yet despite breeding, females were not producing offspring. With the advent of ultrasound in the 1990s, factors inhibiting conception were revealed (Schaffer et al. 1994) (Image 1). The high rate of pathologic abnormalities observed in the reproductive tracts of female rhinos from both Indonesia and Malaysia was initially presented at the 1999 Asian Rhino Specialist Group Meeting, and published shortly thereafter (Schaffer et al. 2002). In addition, pregnancy failure was linked to early embryonic death (Roth et al. 2001).

In early 2001, examination of a poached female in Sabah, Malaysia signaled that the problem was not exclusive to captivity (Image 2). In 2011 and 2014, two more females examined immediately after capture from the same geographic area in Sabah presented with extreme pathologic conditions (Fiuza et al. 2015; Schaffer 2018). The Sumatran Rhino was declared extinct in the rainforests in Malaysia in 2015. This trend will have serious implications for the success of Indonesia's 2018 Emergency Action Plan to build a productive captive population with the last Sumatran Rhinos, as set forth below.

Image 1. Analysis of reproduction in the first captive females was hampered by the lack of portable ultrasound machines. Pictured is Dr. Nan Schaffer with an early prototype in 1998. © SOS Rhino.

RESULTS

This paper is based on records of female Sumatran Rhinos captured or poached from various sites in Indonesia and Malaysia between 1984 and 2018. Available records for husbandry reports, laboratory results, histology, ultrasound images, and reproductive tract examination were compiled by Schaffer (2018). Source data and additional details on individual animals are available on the Rhino Resource Center website. A summary of the data is provided in Table 1, which includes animal identification, approximate age, dates and location of capture, breeding facility location, date of death, whether the animal copulated, examination results, and name of examiner. Age of adults, parous status, and relatedness were unknown with the exception of one genetically related breeding pair (Morales et al. 1997). Despite wide variability in parameters, the type of reproductive diseases were similar among individuals, and the rate of disease occurrence was high

Table 1. Details of the female Sumatran rhinoceros *Dicerorhinus sumatrensis* captured between 1984 and 2018 in Peninsula Malaysia; Sabah, Borneo, East Malaysia; Sumatra, Indonesia and Kalimantan, Borneo, Indonesia. The information includes (where available) date of capture, date of death, given name, facility where kept, approximate age at time of capture, and presence or absence of pathologies, method used and name of examiner. The table includes data on 3 females born in captivity, as well as data on a 2001 poached female found in Sabah.

Stud Book #	Capture location	Capture date	Name	Age at capture	Captive facilities	Date of death	Evidence of copulation	Evidence of pathology date recorded	Method	Examiner
01	Selangor, Malaysia	30.iv.1984	Jeram	Adult	Melaka, Malaysia	10.vii.2002	Yes	Uterine Tumors & Cysts (1991)	Ultrasound	N. Schaffer
03	Malaysia	18.iv.1985	Melintang	N/A	Melaka, Malaysia & Bangkok, Thailand	23.xi.1986	Unknown	No Records		
05	Torgamba, Indonesia	23.i.1986	Riau	Adult	Capture Site	23.i.1986	Unknown	No Records		
07	Johor, Malaysia	10.ii.1986	Rima	Adult	Melaka, Malaysia	12.iv.2003	Yes	Birthed SB15 (1987); Cysts (2001)	Ultrasound	R. Radcliffe
10	Torgamba, Indonesia	22.vi.1986	Subur	Adult	Port Lympne, UK	29.x.1986	No	Uterine Leiomyoma	Histology	C. Furley
11	Selangor, Malaysia	6.vii.1986	Julia	Adult	Melaka, Malaysia	15.xii.1989	No	No Pathology	Gross Pathology	Z. Zahari
12	Malaysia	9.ix.1986	Dusun	~10 Yrs.	Melaka, Malaysia, Jakarta & Way Kambas, Indonesia	7.ii.2001	Yes	Chronic Lactation (1992-2001); Irregular Uterus & Ovaries	Ultrasound Histology	N. Schaffer M. Agil
13	Selangor, Malaysia	25.ii.1987	Panjang	~5 Yrs.	Melaka, Malaysia	9.xi.2003	Yes	Uterine Cysts (1991); Tumors (2002)	Ultrasound	N. Schaffer R. Radcliffe
15	Captive Born to SB07 in Melaka, Malaysia	23.v.1987	Minah	N/A	Melaka, Malaysia	16.xi.2003 15YRS.	Yes	Cysts (2001)	Ultrasound	R. Radcliffe
16	Selangor, Malaysia	1.vii.1987	Seridelima	~7 Yrs.	Melaka, Malaysia	23.ix.1988	No	No Pathology	Gross Pathology	Z. Zahari
18	Torgamba, Indonesia	21.vii.1987	Meranti	Adult	Port Lympne, UK	4.xi.1994	No	Uterine Leiomyoma (noted before death in 1994)	Histology	C. Furley
19	Malaysia	26.viii.1987	Mas Merah	~8 Yrs.	Melaka, Malaysia	17.xi.2003	Yes	Few, Small Uterine Tumors & cysts (1991) Same Findings (2001)	Ultrasound	N. Schaffer R. Radcliffe
22	Torgamba, Indonesia	8.vii.1988	Dalu	Adult	Taman Safari, Indonesia	27.vii.1993	Yes	Multiple Corpus Luteum; Enlarged Uterus (1993)	Histology	N. Schaffer M. Agil
23	Pahang, Malaysia	11.vii.1988	Seputih	~10 Yrs.	Melaka, Malaysia	28.x.2003	Yes	Uterine Cysts (1991); Large Tumor (1998); Tumors, Cysts (2002)	Ultrasound	N. Schaffer R. Radcliffe
24	Bengkulu, Indonesia	22.vii.1988	Mahato	Juvenile	Los Angeles & Cincinnati, USA	10.v.1992	No	Immature Reproductive Tract (1992)	Gross Pathology	N. Schaffer
25	Bengkulu, Indonesia	24.vii.1988	Barakas	~12 Yrs.	San Diego, USA	22.ii.1995	No	Cystic endometrial hyperplasia (1995)	Histology	L. Lowentine
26	Lahad Datu, Malaysia	22.iv.1989	Lun Parai	~6 Yrs.	Sepilok, Sabah, Malaysia	23.viii.2000	Yes	Uterine Tumor and cysts (1998) Leiomyoma (2001)	Ultrasound Histology	N. Schaffer
27	Bengkulu, Indonesia	26.viii.1989	Rapunzel	~6 Yrs.	Los Angeles & New York, USA	22.xii.2005	No	Uterine Tumors and cysts (1994)	Ultrasound	N. Schaffer
29	Bengkulu, Indonesia	6.iii.1991	Emi	~1 Yr.	Los Angeles & Cincinnati, USA	5.ix.2009	Yes	5 Abortions (1998 – 2001); 3 births (2001, 2004, 2007); Cysts (resolved) (2002)	Ultrasound	T. Roth
32	Bengkulu, Indonesia	17.v.1991	Bina	~3 Yrs.	Taman Safari & Way Kambas, Indonesia		Yes	Post productive (2010); Few cysts (2014); Cycling (2019)?	Ultrasound Ultrasound	N. Schaffer T. Roth
33	Bengkulu, Indonesia	12.vi.1991	Rami	~8 Yrs.	San Diego, USA	25.v.1992	Unknown	No Records		L. Lowentine
34	Bengkulu, Indonesia	17.i.1992	Wiwien	~4 Yrs.	Surabaya, Indonesia	12.xi.1996	Unknown	No Records		
40	Tabin, Malaysia	17.vi.1994	Gologob	Adult	Sepilok, Sabah, Malaysia	11.i.2014	Yes	Few uterine cysts (1998); more cysts (2004) Post productive (2010)	Ultrasound Ultrasound	N. Schaffer P. Kretzschmar

Stud Book #	Capture location	Capture date	Name	Age at capture	Captive facilities	Date of death	Evidence of copulation	Evidence of pathology date recorded	Method	Examiner
	Poached Animal Sabah, Malaysia	2001	Female	Adult	Wild, Sabah	N/A	No	Cysts and 3 Leiomyoma (2001)	Histology	N. Schaffer
43	Captive Born to (SB29 +28) Cincinnati, USA	30.vii.2004	Suci	N/A	Cincinnati, USA	30.iii.2014	No	Immature		
45	Bukit Barisan Selatan, Indonesia	30.ix.2005	Rosa	~3 YRS.	Way Kambas, Indonesia		Yes	Tumors & Cysts 5 years post cycling (2015); Early Embryo loss (2018)	Ultrasound	T. Roth
46	Way Kambas, Indonesia	20.ix.2005	Ratu	~5 YRS.	Way Kambas, Indonesia		Yes	2 Abortions (2009–2010); 2 Births (2012, 2016)	Ultrasound	T. Roth
51	Tabin, Malaysia	18.xii.2011	Puntung	Adult	Sabah, Malaysia	15.vi.2017	No	Multiple Uterine Cysts (2012)	Ultrasound	Z. Zahari
57	Danum Valley, Malaysia	10.iii.2014	Iman	Adult	Danum Valley, Sabah	16.xi.2019	No	Uterine Tumors and Cysts (2014)	Ultrasound	Z. Zahari
58	Captive Born to (SB42 + 46) Way Kambas, Indonesia	12.v.2016	Delilah	N/A	Way Kambas, Indonesia		No	Immature		
	Kutai Barat, Indonesia	12.iii.2016	Najaq	Old	Died at Capture Site	5.iv.2016	No	No pathology, but ovaries and uterus quiescent	Gross Pathology	M. Agil
	West Kutai, Indonesia	25.xi.2018	Pahu	Old	Kelian (Kalimantan) Indonesia		No	Ovarian Tumor (2019)	Ultrasound	M. Agil

Image 2. A poached wild animal's reproductive tract has extensive pathology. O (ovary), C (cervix), T (tumor). © Nan Schaffer.

in all geographic areas of origin and all geographic areas of captivity, including breeding sanctuaries in Indonesia (Sumatra and Kalimantan), Malaysia (Peninsular and Sabah), and all zoos and reserves in the United States and United Kingdom.

Reproductive analysis of captured animals prior to 2000 was sporadic. Hampered by a lack of equipment and limited expertise, only three animals were examined after death at capture. Thus, potential disease processes and conditions affecting reproduction such as early embryo death remained unidentified and unrecorded until monitoring was implemented on a consistent basis. By 2000, a broader base of available expertise, protocols and reporting standards ensured that the last seven females captured: a poached female, Ratu, Rosa, Puntung, Iman, Najaq, and Pahu were examined and reproductively monitored from the beginning of their captive status. Since 1984, of the 32 females brought into captivity, analyses of the reproductive tract were available for 25 because three animals had not reached maturity and four had no records. Out of 25, 22 individuals (88%) presented with some kind of reproductive disease. Out of the 22 animals, 14 females did not conceive despite copulating a few to several times and eight females were without access to a breeding male. Females copulated even if they had pathology.

Cysts and Tumors

Uterine cysts and tumors were the most frequently documented reproductive problems (42%), and were primarily noted on ultrasound evaluation. Gross visualization of intraluminal cysts was noted in a female that died in captivity in 2000 (Lun Parai). A female poached in 2001 had numerous tumors and cysts. Histology reports regarding the endometrium were

available for only two females: endometrial edema (Dalu) and cystic endometrial hyperplasia (Barakas).

Histopathology on the uterine masses of six animals confirmed leiomyoma. The ultrasound images of these tumors were consistent with signs of smooth muscle fibroma (dense, round circumscribed) and firm on palpation. Tumors occurred in three obviously older animals (Rapunzel, Jeram, Subur), five adults (Lun Parai, Meranti, Mas Merah, Iman, and a poached female), and one young female (Rosa). The tumors present in Mas Merah had not changed when examined 10 years after the original exam. Two animals Panjang and Seputih both presented with only a few cysts when initially examined. Follow-up exams 10 years later revealed that each had developed tumors in the both the vagina and uterus. Abnormalities were also observed in younger animals. Minah, who was born in captivity, had cysts by 14 years of age, but this may have been due to her exposure to exogenous hormones. Another juvenile, Rosa, began cycling in 2010 and began to develop pathology in 2015 (Ferawati et al. 2018).

Early Embryo Death

When ultrasound was finally applied consistently enough to monitor for signs of pregnancy, animals were found to be losing embryos. Three monitored animals (Emi, Ratu and Rosa) entered captivity young, but subsequently had difficulty maintaining pregnancy. First time pregnancies might account for first time abortions, but it was unclear why multiple spontaneous abortions (Emi 5; Ratu 2) occurred thereafter. Rosa was reluctant to breed when she began to cycle and a few years later she developed significant pathology and is currently losing embryos.

Unusual Findings

Two females in residential zoos, Dalu (Taman Safari, Bogor, Indonesia) and Dusun (Melaka, Malaysia and Ragunan, Jakarta, Indonesia) had unusual histories and pathological findings. Dalu's reproductive tract had multiple corpus luteum and a significantly enlarged uterus that revealed edema with hemosiderin without evidence of infection. After breeding, Dusun lactated for nine years before her death. Findings on necropsy noted chronic cystic kidney disease and darkening of multiple organs, including the skin, suggesting hemosiderosis.

Infection

No signs of infections were identified in the few histological reports provided. One female (Panjang) displayed possible infectious processes such as fluid in the lumen of the uterus. Iman demonstrated a large tumor and pyometra that cultured as alpha and beta hemolytic streptococcus at the time of capture. She subsequently died when the large tumor finally interfered with her urinary tract.

DISCUSSION

Infections of the uterus were rarely observed in the Sumatran Rhino, which is consistent with findings reported in other species of rhinoceros by Hermes & Hildebrandt (2011). Nutritional factors apparently influenced the development of abnormal conditions in two animals. The predominant signs of reproductive failure identified in this species are uterine cysts, uterine tumors, uterine hyperplasia, and early embryonic loss, all of which are indicative of hormonal imbalances. Hormonal imbalances can be associated with the factors of age, lack of parity, and the aberrant genetics inherent in non-producing (isolated) and inbred animals.

Nutrition

Although multiple corpora lutea can be a normal occurrence in horses and camelids, the greatly enlarged uterine endometrium in one rhinoceros and prolonged lactation in another indicated disease. The unusual conditions in both Dusun and Dalu occurred in the presence of hemosiderosis. Both of these animals were in residential zoo settings where proper foods were not readily available, and they died before nutritional requirements for this species were elucidated.

Effects on the reproductive system could have stemmed from direct deposits of iron into the reproductive organs of rhinos, a process that can evidentially turn the endometrium dark brown (Nan Schaffer, pers. obs. 1992), or indirectly from iron deposition into organs such as the kidney that influence hormone levels. Kidney failure was the most commonly reported cause of death in the Sumatran Rhinoceros after gastrointestinal disease (Foose 1999).

An uncommon symptom of chronic kidney disease is galactorrhea whereby chronic nephritis results in a lack of clearance of the hormone prolactin (Hou et al. 1985). Dusun was the only animal to present with this syndrome, and she was also the only one that demonstrated signs of late pregnancy loss. The histology report on Barakas (San Diego Zoo) showed the multiple system-wide occurrence of hemosiderosis, which was also evident in this animal's cystic, hyperplastic endometrium.

The last two animals to die of hemosiderosis

were a breeding female (Emi) and her offspring (Suci) at the Cincinnati Zoo. The fact that their diets had been improved considerably over time may have relieved effects on the reproductive system. Deaths from iron overload have become rare as a result of the improved diet available in semi-wild sanctuaries located in Indonesia and no animals have succumbed to hemosiderosis since Suci's death in 2014.

Age

Cysts are most closely associated with age in horses, and are found in 22% of adult mares and 55% of older mares (Wolfsdorf 2002). Even though cysts seem to develop as rhinos aged, some apparently younger animals (Minah, Emi and Rosa) also developed cysts.

Tumors are associated with non-productive females (Hermes et al. 2004) and have been documented in rhinos as young as 15 years of age (Montali & Citino 1993). The fact that Rosa, a young non-productive Sumatran female, developed pathology five years after maturity is an ominous sign for animals in the wild that are unable to stay consistently pregnant. The progressive nature of the disease was also evident in Rosa, who initially had few cysts and then developed a tumor. This was observed in two additional non-productive animals, who progressed from having cysts to several tumors. The fact that there are fewer and fewer signs of offspring in many of the small, scattered remaining populations of the Sumatran Rhino may be an indication of development of this disease, which results in the loss of fertility.

Protection of Parity

In other species, parity may provide some protection from developing reproductive pathology (Parazzini et al. 1988; Hermes et al. 2004). The parous state of the Sumatran Rhino has been difficult to assess because the majority of animals were adult when captured and hymens were rarely checked when individuals entered captivity. Most reports of the condition of the hymen are connected with attempts to break the hymen of the female after the male had difficulty copulating with her. Parity was confirmed in only three animals.

Rima gave birth just after entering captivity, yet despite regular breeding thereafter, she did not become pregnant. The fact that she did not develop cysts until her later years, suggests that her pregnancy protected her from pathology.

High rates of pathology in females may occur because they were non-productive before they entered captivity and remained so afterwards.

Reduced Parity with Early Senescence

An analysis of reproductive events in the captive population of Sumatran Rhinoceros suggests that premature senescence occurs in non-productive females. Ordinarily in mammals, except for humans, reproductive life typically lasts up until the end of life. Three older animals had a long period wherein the ovaries were inactive before death: Jeram was post-productive for 10 years, Rapunzel for 10 years, and Gologob for four years. Bina has never conceived despite multiple attempts with one male and is presently reluctant to breed with new males, which may indicate beginning senescence. Premature senescence with high rates of reproductive pathology, termed "asymmetric reproductive ageing" in captive White and Indian Rhinoceroses, reduces the production of offspring in females that experience a prolonged lack of pregnancy (Hermes et al. 2004). Notably, pregnancy is common in herds of older White Rhinoceroses in the wild, suggesting that this may not be a problem in these herds (Kretzschmar, pers. comm. 2018). In the Sumatran Rhinoceros, among the last seven captured females five presented (soon after capture) with either pathology or as older animals with quiescent reproductive tracts suggesting they had reduced breeding opportunities in the wild.

Inbreeding Effects

Small populations often suffer the effects of inbreeding depression. Deleterious alleles may have been expressed in Sumatran Rhinoceros males and females which can predispose females to disease processes such as fibrous tumors (Medikare et al. 2011). The heritable component of hemosiderosis may have been demonstrated when Suci, an offspring from a pair of closely related parents, died from genetically related iron sensitivity (Morales et al. 1997). While Suci's brothers survived and became productive, she and her mother succumbed to hemosiderosis. Moreover, recessive alleles have been directly expressed as problematic reproductive morphologies, including an abnormal male penile skin attachments and intact "imperforate" hymens in two captive females that had their hymens manually broken before copulation could succeed (Filkins 1965; Tibary 2016).

Attempting to breed animals from highly inbred populations will severely compromise production. The effective number of breeders is now so low that recovery of genetic vigor will require careful genetic mixing. Therefore, infusion of genetic resources from animals in Kalimantan and the exchange of genetic resources between rhinos from the northern and southern areas

of Sumatra will be vital for this species survival.

Treatment

Only after females could be closely monitored within a captive setting could early pregnancy loss be diagnosed and treated with drugs that prevent embryo loss in other rhinoceros species (Berkeley et al. 1997; Roth et al. 2004). To date, all females that have delivered offspring in captivity have been medicated with progesterone supplements, as demonstrated by Schaffer et al. (1995).

Treatments become increasingly less successful the more pathology a female develops. Certain types of cysts are more problematic, but this cannot be confirmed without a biopsy. Though only one cystic endometrial hyperplasia has been reported, this condition may have been more common. Uterine biopsy could be a useful tool in elucidating the reproductive condition of individuals. Difficulties sampling the uterine tissue of larger species of rhinoceros have been overcome and access to the uterus of the Sumatran Rhino has been accomplished (Radcliffe et al. 2000; Hermes et al. 2009).

Extensive numbers of cysts and/or tumors will interfere with maintenance of pregnancy. In domestic horses, treatment of cysts involves mechanical intervention such as aspiration or hormonal removal. Procedural complications and reoccurrence of the cysts is common. To date, treatment of cysts in Sumatran Rhinos with extensive pathology has been unsuccessful and resulted in the return of cysts (Fiuza et al. 2015). Emi developed a few cysts between successful pregnancies, indicating it may be possible for females to achieve pregnancy when cysts are minimal. Although mares have achieved pregnancy with mild cases of only a few cysts, Panjang and Seputih were breeding with negligible cysts, but neither produced offspring. Unfortunately, like most animals captured during the 1980's and 1990's, it was impossible to determine whether or not uterine cysts interfered with embryos in these individuals. The monitoring of Rosa has revealed that she has developed cysts and a tumor. Embryos are also forming with breeding, but she is not maintaining her pregnancies despite progesterone treatments. Unlike Ratu and Emi whose healthy, pathology-free uteri responded successfully to progesterone treatments, Rosa is unlikely to become pregnant even with progesterone. Thus, Rosa's only chance to contribute to the recovery of this species is through the application of Advanced Reproductive Techniques.

Leiomyomas were the most common type of reproductive tumors in the rhinoceros (Montali & Citino 1993). Hermes & Hildebrandt (2011) described species differences among rhinos in the typical location of tumors, in the reproductive tract. Indian Rhinos typically develop vaginal tumors, White Rhinos typically develop uterine tumors, and Sumatran Rhinos develop both. Early cases of uterine tumor removal were not successful in the Sumatran and Indian Rhinoceros (Klein et al. 1997; Foose 1999). Although a few vaginal tumors have been removed, there has not been a further attempt to remove uterine tumors thus far (Radcliffe 2003). Some hormone treatments show promise in shrinking these tumors (Hermes et al. 2016). Other treatment regimens useful for domestic animals have been explored for non-productive female Sumatran Rhinoceroses (Radcliffe 2003). Unfortunately, these animals died before treatment effects could be ascertained. Animals with pathology will be difficult and time consuming to recover.

Ramifications for Female Sumatran Rhinos

Reproductive problems prevalent in small, isolated, inbred populations of Sumatran Rhinos in captivity are also evident in animals in the wild. The first indication that pathology could be a problem in populations in the wild was observed in 1986 with the capture of the first animal in Indonesia. The discovery of tumors at the necropsy of this female within four months of entering captivity suggested that she developed the tumors before she was captured (Furley 1993). Early capture efforts focused on capturing "doomed" animals (Nardelli 2014), many of which had or later developed reproductive problems. The prevalence of reproductive problems in females, however, became evident in the wild after 2000 when animals were routinely examined immediately after capture. Since 2001, newly captured females have also been from "doomed" areas. Fertility problems have been pervasive in these "rescued" females. All seven of these female Sumatran Rhinos captured had reproductive problems: five had reproductive abnormalities that were observed immediately after capture, and early embryonic death was subsequently observed in two animals. A high rate of infertility is inherent in small inbred populations with isolated females, and it continues to interfere with the growth of captive and wild populations.

The existence of pathology in females suggests they have had few, if any, offspring in the wild, and indeed there is no evidence of births in the areas where rhinos have recently been captured in Sumatra (Bukit Barisan Selatan and Way Kambas National Parks) and Sabah (Tabin Wildlife Reserve and Danum Valley). These areas have seen precipitous drops in rhino populations. For example Way Kambas had 26–31 rhinos according to the

2015 population viability analysis (Miller et al. 2015), while recent observations indicate the population now numbers 4–9 rhinos (Marcellus Adi pers. comm. 2019). Areas with steadily declining populations and little evidence of offspring will continue to provide predominately reproductively compromised animals.

Credible demographic information about populations is nonexistent, except for the fact that they are disappearing. To date, no population assessment tool or combination of tools including surveys, camera-traps, and fecal DNA analyses has provided the critical fertility information required to manage this species in the wild. Camera-trap photographs of a few females with young can only provide information on where potentially fertile rhinos can be found; it does not define or confirm the ongoing viability of the current population or survival of the species. Realistic information applicable to the Sumatran Rhino should have been used for successful modeling of extinction outcomes for this species (Miller et al. 2015). For years we have had all the information we needed to show that the Sumatran Rhino in Indonesia can no longer be sustained in the wild, particularly in the face of mounting infertility and negative growth rates, even with the absence of poaching.

Fertile females are the determinant factor in the recovery of this Critically Endangered species (Kretzschmar et al. 2016). When numbers are critically low and the risk of infertility so high, the fertility status of every female rhinoceros must be ascertained and constantly monitored, which is not possible when the status of animals is unknown. Intensive management zones (IMZs) and/or intensive protection zones (IPZs) are not suitable for this cryptic rainforest species, because the information necessary for successful management cannot be obtained within such areas (Ahmad et al. 2013; Payne & Yoganand 2018). Although these management strategies may apply to the larger African and Asian rhinoceros populations, which can be observed, monitored and sampled at the individual level, these strategies are inappropriate and dangerously non-productive for the Sumatran Rhino (Image 3). The only way to determine the fertility status of an individual Sumatran Rhino is through direct, hands-on examination in a captive setting.

After 25 years of perfecting tools and techniques in captivity, the Sumatran Rhino Sanctuary (SRS) design in Way Kambas is currenly the only option for successful reproductive management of Sumatran Rhinos. Only in this environment can the essential management information be obtained, and reproduction optimized. Fertility monitoring for this species requires confirming reproductive events by comparing ultrasound images with individual hormonal levels in feces or blood. Treatment protocols for pathology have been attempted but need further development (Radcliffe 2003). Simulation or inducement of pregnancy may be the only prevention (Roth 2006; Hermes & Hildebrandt 2011; Hermes et al. 2016; Roth et al. 2018). Females have been successfully assisted with the maintenance of their pregnancies, and offspring have resulted. Other techniques are evolving quickly to optimize production in this species (Galli et al. 2016) even though minimal and marginal genetic material has been available. As happened with the Northern White Rhino, soon there will be little genetic material left for preserving the last record of the Sumatran Rhino (Saragusty et al. 2016; Nardelli 2019). The success of a single genetically distinct union could revitalize this Critically Endangered species. None of these conditions will be identifiable or treatable while animals are in the wild. Time is running out for younger treatable animals, which without pregnancy are at risk of rapidly developing pathology, given that Rosa developed pathology in less than five years.

Image 3. In contrast to decades of unreliable surveys, direct observation and analysis has been the only source of relevant information for productive management. © Nan Schaffer.

CONCLUSION

The critically low estimates of numbers in widely scattered populations of the Sumatran Rhino, coupled with the fact that both captive populations and animals caught from the wild are largely reproductively compromised, means that only a small number of reproductively viable animals may be left in the wild. In addition, the complete lack of relevant information, and in some cases wild extrapolations, on the status of animals makes addressing these problems in the

wild impossible. In light of these facts, building a new productive captive population by starting immediately with capturing viable, productive animals from the onset and optimizing their production is essential. Recovery and use of vital genetic materials must be accelerated before these resources are lost. Fertile animals must be the first priority for the few sanctuary spaces that are available. The best chance of obtaining fertile founders exists in the few clusters where females with young have been confirmed with recent camera-trap photos. These will also be the areas where females are at risk of fewer pregnancies, but may still be recoverable with treatment. Only two such areas have provided such evidence: Way Kambas National Park (Lampung, southern Sumatra) and certain areas of the Leuser ecosystem (Aceh, western Sumatra). They are the first focus areas for capturing viable females, before they, too, are lost.

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Bahasa Indonesia Abstrak: Badak Sumatera *Dicerorhinus sumatrensis* berada di ujung kepunahan. Penurunan spesies ini pada awalnya dikaitkan dengan perburuan liar dan hilangnya habitat, tetapi bukti yang disajikan di sini menunjukkan bahwa kegagalan reproduksi juga telah menjadi penyebab utama hilangnya, dan terus mempengaruhi penurunan populasi liar. Populasi badak Sumatera yang tersisa di Indonesia adalah kecil dan tersebar, dengan akses terbatas ke peluang berkembang biak dengan pasangan yang tidak berkerabat. Kondidi tersebut mengakibatkan terjadinya inbreeding dan mengakibatkan infertilitas-akibat terisolasi, berhubungan dengan masalah kesuburan yang dianalisis dalam tulisan ini. Betina badak Sumatera di penangkaran menunjukkan tingkat patologi reproduksi dan / atau masalah dengan konsepsi yang tinggi (> 70%) yang secara signifikan menghambat program pengembangbiakannya. Kemajuan teknologi memungkinkan pemeriksaan segera setelah penangkapan dan menunjukkan tingkat dan jenis masalah reproduksi yang sama tingginya pada individu dari populasi liar. Tujuh Badak Sumatera betina yang terakhir ditangkap berasal dari daerah dengan populasi kecil yang menurun, dan ditemukan enam badak memiliki masalah reproduksi. Badak-badak yang tidak reproduktif selanjutnya akan mengambil ruang berharga dan sumber daya yang dibutuhkan untuk hewan subur. Risiko tinggi infertilitas dan kesulitan mengobati penyebabnya, ditambah dengan terus menurunnya jumlah badak yang tersisa di alam, maka keberhasilan upaya untuk membangun populasi badak dipenangkaran yang layak akan sangat tergantung pada pemanfaatan hewan subur dan penerapan teknik reproduksi berbantuan. Survei in situ yang lengkap dalam beberapa dasawarsa belum memberikan informasi yang relevan dengan manajemen populasi atau untuk memastikan status kesuburan masing-masing hewan. Dengan demikian Prioritas pertama dalam penyelamatan badak di alam adalah penangkapan individu sebagai sumber darah baru dari daerah dengan kemungkinan tertinggi mengandung badak subur, ditunjukkan oleh foto dari dari badak betina dengan anak-anaknya dari perangkap kamera yang baru-baru ini ditemukan. Daerah tersebut termasuk Way Kambas dan bagian ekosistem Leuser untuk saat ini di wilayah Sumatera.

Author details: Nan Schaffer's (M.S., D.V.M.), seminal work on reproduction of rhinoceroses, since her residency at the Bronx Zoo in 1981, resulted in the first extraction of semen with electroejaculation and the first ultrasound of the female reproductive tract. She was the first to identify the high prevalence of reproductive pathology in female Sumatran Rhino, which she has reported on since 1991. Muhammad Agil (M.Sc. Agr., D.V.M., Dipl. A.C.C.M.) is a senior lecturer and researcher at the Faculty of Veterinary Medicine, IPB University. He has studied the reproductive biology and conservation needs of the Sumatran Rhino since 1993. His work and research interests also include the Javan Rhino, Banteng and Sumatran Elephant. Zainal Zainuddin (D.V.M.) is a wildlife veterinarian who was involved with Sumatran Rhino capture, captive management, and assisted reproductive technologies in Malaysia and Indonesia. Since his work began in 1985, he has handled the veterinary care and pathological analysis of over 20 individual rhinos. He has over 20 publications on this species.

Author contribution: This paper represents decades of collaborative field work and research among these three colleagues in their shared mission to recover the Sumatran Rhino genus. N. Schaffer compiled the data and wrote the manuscript. All authors reviewed and approved the final manuscript.

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COMMUNICATION

Diet ecology of tigers and leopards in Chhattisgarh, central India

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Abstract: Wild prey base is a potential regulatory parameter that supports successful propagation and secured long term survival of large predators in their natural habitats. Therefore, low wild prey availability with higher available livestock in or around forest areas often catalyzes livestock depredation by predators that eventually leads to adverse situations to conservation initiatives. Thus understanding the diet ecology of large predators is significant for their conservation in the areas with low prey base. The present study reports the diet ecology of tiger and leopard in Udanti Sitanadi Tiger Reserve and Bhoramdeo Wildlife Sanctuary, in central India to know the effect of wild prey availability on prey predator relationship. We walked line transects to estimate prey abundance in the study areas where we found langur and rhesus macaque to be the most abundant species. Scat analysis showed that despite the scarcity of large and medium ungulates, tiger used wild ungulates including chital and wild pig along with high livestock utilization (39%). Leopards highly used langur (43–50 %) as a prime prey species but were observed to exploit livestock as prey (7–9 %) in both the study areas. Scarcity of wild ungulates and continuous livestock predation by tiger and leopard eventually indicated that the study areas were unable to sustain healthy large predator populations. Developing some strong protection framework and careful implementation of the ungulate augmentation can bring a fruitful result to hold viable populations of tiger and leopard and secure their long term survival in the present study areas in central India, Chhattisgarh.

Keywords: Food habit, large predators, livestock depredation, wildlife conservation.

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Competing interests: The authors declare no competing interests.

Author details: Krishnendu Basak's responsibilities at Wildlife Trust of India (WTI) include mitigating man-animal conflict mostly with tiger and study conflict dynamics in the Sundarban landscape. Moiz Ahmed is actively involved with the state forest department in Wild Buffalo conservation program, snake rescue, and release project in state capital Raipur and also conducted tiger monitoring and population estimation exercises in Chhattisgarh. M. Suraj actively participated as a researcher during Phase IV tiger monitoring and All India Tiger Estimation, 2018 across various protected areas of Chhattisgarh, trained forest staff on snake rescue and AITM data collection procedure, and assisted in data collection and management for the same. B.V. Reddy (IFS) was the deputy director of Udanti Sitanadi Tiger Reserve, Gariyaband during the study period. O.P. Yadav (IFS) was the field director of Udanti Sitanadi Tiger Reserve, Chhattisgarh during the study period. Dr. Krishnendu Mondol is presently associated with Ministry of Environment, Forest and Climate Change.

Author contribution: KB provided technical inputs for the study, guidance for data collection and technical writing. MA conducted field work, data collection, and management. MS managed field work, data collection, training, and capacity building. BVR and OPY provided permissions for the study and logistical & financial support. KM provided technical inputs for the study, guidance for data collection, and technical writing.

For **Acknowledgements** and **Hindi abstract** see end of this article.

INTRODUCTION

Investigating diet composition of a predator is vital to indicate the adequacy of prey base and understand prey requirements. Fluctuations in prey abundance may induce changes in dietary selection and the rate of prey consumption by predators (Korpimäki 1992; Dale et al. 1994). Prey selection by large carnivores is a vital strategy to maintain their population growth and their distribution in space and hence, it becomes essential to understand the life history strategies of carnivores for better management practices (Miquelle et al. 1996).

Generally, the tiger *Panthera tigris* as a large solitary predator requires >8 kg of meat daily to maintain its body condition (Schaller 1967; Sunquist 1981). It hunts a varied range of prey species based on their availability in a particular landscape; this may include large bovids such as Indian Gaur (Karanth & Sunquist 1995) to small animals like hares, fish, and crabs (Johnsingh 1983; Mukherjee & Sarkar 2013). Tigers, however, prefer prey species that weigh 60–250 kg and this indicates the conservation significance of large-sized prey species in the maintenance of viable tiger populations (Hayward et al. 2012). Whereas, plasticity in leopard *Panthera pardus* behavior (Daniel 1996) enables them to exploit a broad spectrum of prey species which makes them more adaptable to varied range of habitats. Large carnivores show high morphological variations (Mills & Harvey 2001) across their distribution ranges which in turn regulate their dietary requirements. The number of prey items in a leopard's diet can go up to 30 (Le Roux & Skinner 1989) or even 40 species (Schaller 1972). Leopards consume prey items ranging from small birds, rodents to medium and large-sized prey such as Chital *Axis axis*, Wild Boar, Nilgai and Sambar to domestic prey like young buffalo, and domestic dogs in the Indian subcontinent (Eisenberg & Lockhart 1972; Santiapillai et al. 1982; Johnsingh 1983; Rabinowitz 1989; Seidensticker et al. 1990; Bailey 1993; Karanth & Sunquist 1995; Daniel 1996; Edgaonkar & Chellam 1998; Sankar & Johnsingh 2002; Qureshi & Edgaonkar 2006; Edgaonkar 2008; Mondal et al. 2011; Sidhu et al. 2017). Hayward et al. (2012) categorized Leopard as a predator that exploits over one hundred prey species but prefers to kill prey items within 10–50 kg body weight which may deviate to 15–80 kg (Stander et al. 1997), depending on their hunger level, hunting efforts and sex (Bothma & Le Riche 1990; Mondal et al. 2011).

Apart from the natural prey-predator relationship, tigers and leopards are reported to consume domestic ungulates as a large proportion of their diet during scarcity of wild prey. Hunting and habitat destruction are the major reasons behind the decline of wild prey availability. The distribution ranges of tigers and leopards are mostly interspersed and overlapped with human habitations. In such situations, there are abundant records of carnivores hunting livestock which in turn frequently leads to retaliatory killing of the predators or escalates human tiger or leopard conflict. It has become a serious issue and can be considered as one of the toughest hurdles to resolve in large carnivore conservation and management. In India these large carnivores are gradually confined within the fragmented forest habitats that share sharp boundaries that home dense human populations. Areas like these experience intensive grazing by domestic and feral cattle, and simultaneous forest resource utilization by local people have been degrading tiger habitats in terms of retarded growth of vegetation, increase in abundance of weeds and ultimately depletion of natural prey base (Madhusudan 2000). As a consequence of increase in livestock and depletion of natural prey base, carnivores are compelled to prey on the domestic livestock (Kolipaka et al. 2017).

Studies have already been conducted to understand the feeding ecology of tiger and leopard in many parts of the Indian sub-continent but, there are only few studies available where diets of both the top predators have been studied together (Sankar & Johnsingh 2002; Ramesh et al. 2009; Majumder et al. 2013; Mondal et al. 2013). To gather knowledge on the complex diet ecology and prey-predator relationship of tiger and leopard, the present study was conducted in two different protected areas in Chhattisgarh, central India with the objectives to understand the food habits of leopard in absence of tiger (in Bhoramdeo Wildlife Sanctuary) and in presence of tigers but with low prey abundance (Udanti Sitanadi Tiger Reserve). The present study was conducted in Bhoramdeo Wildlife Sanctuary (BWS) from March 2016 to June 2016 and in Udanti Sitanadi Tiger Reserve (USTR) from December 2016 to June 2017. Studying large predator diet is always useful for park managers because it provides very relevant information on prey species utilization by large carnivores. The present study will eventually attribute to such important aspects of resource management of the large carnivore populations in both the study areas.

MATERIALS AND METHODS

Study areas

BWS is spread over 351.25km^2 and situated in the Maikal Range of central India (Figure 1). It provides an extension to the Kanha Tiger Reserve as well as serves as a corridor for dispersing wildlife between the Kanha and Achanakmar Tiger Reserves (Qureshi et al. 2014). Bhoramdeo is mostly dominated by *Shorea robusta*. A mixture of tropical dry and mixed deciduous forest types with bamboo brakes formed the vegetation of the sanctuary (Champion & Seth 1968). Tiger, leopard, Sloth Bear *Melursus ursinus*, and Dhole *Cuon alpinus* are reported as large carnivores in the area. Major ungulates are Chital *Axis axis*, Barking Deer *Muntiacus vaginalis*, Sambar *Rusa unicolor*, Four-horned Antelope *Tetraceros quadricornis*, Indian Gaur *Bos gaurus*, Nilgai *Boselaphus tragocamelus*, and Wild Boar *Sus scrofa*. Two commonly found primates in BWS are Northern Plains Gray Langur *Semnopithecus entellus* and Rhesus Macaque *Macaca mulatta*. Smaller carnivores include the Jungle Cat *Felis chaus*, Indian Fox *Vulpes bengalensis*, and Golden Jackal *Canis aureus*.

USTR is spread over 1842.54km^2 of Gariyaband and Dhamtari districts of Chhattisgarh, central India (Figure 1). It is constituted with Udanti and Sitanadi Wildlife Sanctuaries as cores and Taurenga, Indagaon and Kulhadighat Ranges as buffer. The topography of the area includes hill ranges with the intercepted strips of plains. The forest types are chiefly dry tropical peninsular sal forest and southern tropical dry deciduous mixed forest (Champion & Seth 1968). Sal is dominant, mixed with *Terminalia* sp., *Anogeissus* sp., *Pterocarpus* sp., and bamboo species. The Tiger is the apex predator in the area and other co-predators are Leopard, Dhole, Indian Grey Wolf *Canis lupus*, Striped Hyena *Hyeana hyena* and Sloth Bear. Chital, Sambar, Nilgai, Four-horned Antelope, Barking Deer, Wild Boar, Gaur, and Indian Mouse Deer *Moschiola indica* represent the ungulate prey base in USTR. Smaller carnivores include the Jungle Cat *Felis chaus*, Rusty-spotted Cat, *Prionailusrus rubiginosus*, and Golden Jackal *Canis aureus*.

USTR is contiguous with Sonabeda Wildlife Sanctuary (proposed tiger reserve) in Odisha on the eastern side and forms Udanti-Sitanadi-Sonabeda Landscape. This connectivity has a good future if the entire tiger landscape complex (Chhattisgarh-Odisha Tiger Conservation Unit) can be taken under significant wildlife conservation efforts.

Prey abundance estimation

Line transect method under distance sampling technique was followed to estimate the prey abundance in both the study areas (Anderson et al. 1979; Burnham et al. 1980; Buckland et al. 1993, 2001). In total, 29 transects in BWS and 108 transects in USTR were laid according to their areas and surveyed during the study period (Figure 1). Each transect was 2km in length and walked three times in BWS and 5–6 times in USTR between 06.30 and 08.30 h on different days. The total effort of the transect samplings was 174km and 974km for BWS and USTR, respectively. The data were recorded for six ungulate species, viz., Chital, Sambar, Gaur, Wild Boar, Barking Deer, and Nilgai in both the study areas. The other species recorded during the transect walk were Northern Plains Gray Langur and Rhesus Macaque. On each sighting of these species the following parameters were recorded, a) group size, b) animal bearing, and c) radial distance (Mondal et al. 2011). Radial distance and animal bearing were measured using range finder (HAWKE LRF 400 Professional) and compass (Suunto KB 20/360), respectively.

The key to distance sampling analyses is to fit a detection function, g(x), to the perpendicular distances from the transect line and use it to estimate the proportion of animals missed by the survey (Buckland et al. 2001), assuming that all animals on the line transect are detected (i.e., g(0) = 1). The assumptions of distance sampling have been discussed by Buckland et al. (2001). Program DISTANCE ver. 6 was used to estimate prey density. The best model selection was carried out by the generated values of Akaike information criterion (AIC; Akaike 2011). Population density (D), cluster size, group encounter rate and biomass (body weight of prey species x density) for each species was calculated in the present study.

Food habits estimation

The food habits of leopards and tigers were estimated following scat analysis methods (Sankar & Johnsingh 2002; Link & Karanth 1994; Mondal et al 2011; Basak et al. 2018). Tiger and leopard scat samples were collected during the sign survey along the trails in the study areas. Scats were collected opportunistically whenever encountered, irrespective of fresh or old condition to increase sample size. Scat samples were collected from entire BWS and North Udanti, South Udanti, Taurenga, and Kulhadighat ranges of USTR. In total 100 leopard scats were collected from BWS, 30 tiger scats and 121 leopard scats were collected from USTR for diet analysis. Tiger and leopard scats were differentiated on the basis

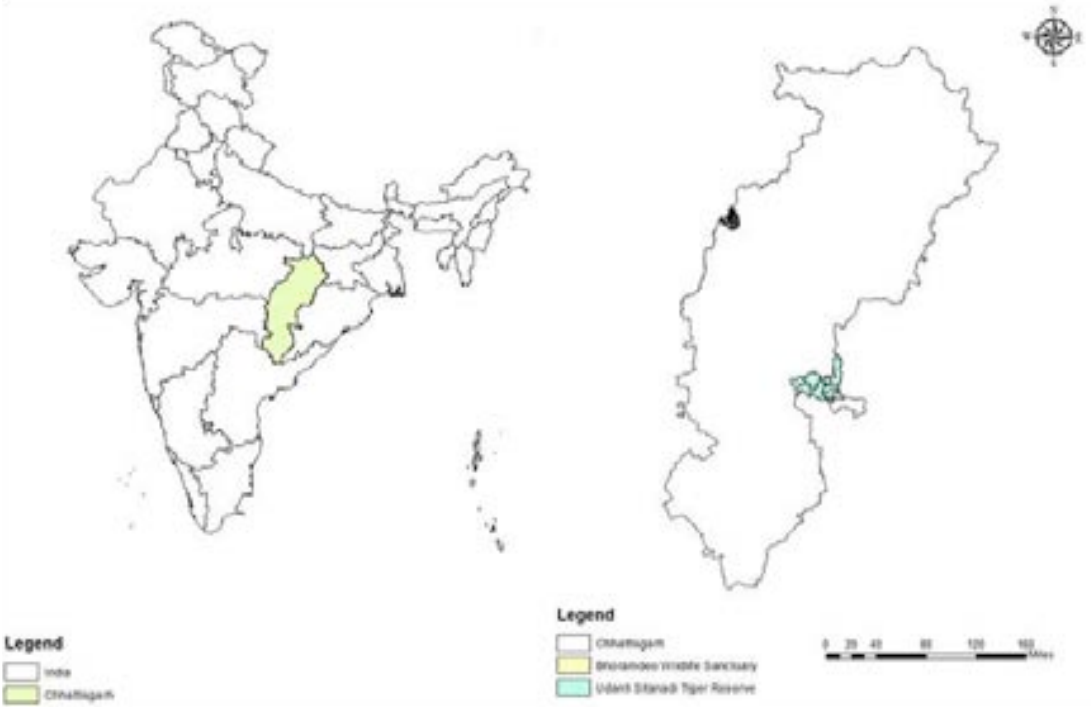

Figure 1. The locations of Udanti-Sitanadi Tiger Reserve and Bhoramdeo Wildlife Sanctuary in the state of Chhattisgarh, central India.

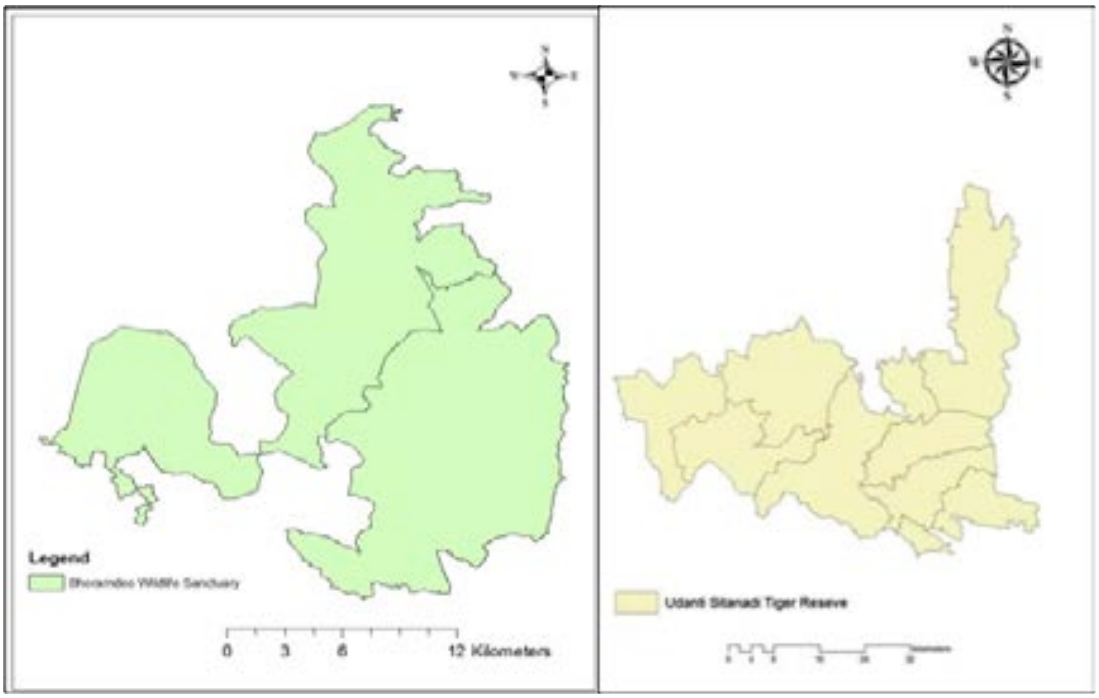

Figure 1a. Bhoramdeo Wildlife Sanctuary on left side and Udanti Sitanadi Tiger Reserve on right side.

of degree of lesser coiling and larger gap between two constrictions in a piece of tiger scat (Biswas & Sankar 2002). Scat analysis was performed to derive frequency of occurrence of consumed prey items in the scats of tiger and leopard (Schaller 1967; Sunquist 1981; Johnsingh 1983; Karanth & Sunquist 1995; Biswas & Sankar 2002).

Scats were first sun-dried then washed using sieves and collectible hairs, bones, feathers were filtered out.

The hair samples were dried and collected in zip-lock polythene bags for further lab analysis. In laboratory, hairs were washed in Xylene and later mounted in Xylene (Bahuguna et al. 2010) and slides were studied under 10–40 X using a compound light microscope. For each sample at least twenty hairs (n=20 hairs/ sample) were selected randomly for diet identification and species level identification has been done based on species-specific hair medulla pattern of prey items as described by Bahuguna et al. (2010). To evaluate the effect of sample size on results of scat analysis (Mukherjee et al. 1994a,b), five scats were chosen at random and their contents analyzed. This was continued till n=100, n= 30 and n=121 scat samples were analyzed and cumulative frequency of occurrence for each prey species was calculated to infer the effect of sample size on the final result (Mondal et al. 2011). Quantification of prey biomass consumed from scat was computed by using the asymptotic, allometric relationship equation; biomass consumed per collectable scat/predator weight = $0.033–0.025\exp^{-4.284(\text{prey weight/predator weight})}$ (Chakrabarti et al. 2016). Prey selection of tigers and leopards was estimated for each species by comparing the proportion of the prey species utilized from scats with the expected number of scats available in the environment for each of prey species consumed (Karanth & Sunquist 1995) in SCATMAN (Link & Karanth 1994). Prey selection was also determined by using Ivlev's index (Ivlev 1961), where E= (U-A)/ (U+A), U=relative frequency occurrence of prey species in predators' scat and A=Expected scat proportion in the environment.

RESULTS

Prey abundance

In BWS, Rhesus Macaque was found to be the most abundant species and its estimated density was 24.03 animals ± 7.34 (SE)/km² followed by langur 21.82 animals ± 2.45 (SE)/km². Among ungulates, Chital density was found to be the highest (12.86 ± 5.85 (SE)/km²) followed by Wild Boar (7.1 ± 2.9 SE/km²), Nilgai (5.82 ± 2.53 SE/ km²), Barking Deer (5.74 ± 1.3 SE/km²), and Sambar (0.95 ± 0.48 SE/km²) (Table 1). The density of hare was found to be 1.04 ± 0.48 SE/km² and for Indian Peafowl it was 6.55 ± 2.65 SE/km² (Table 1).

In USTR, Northern Plains Common Langur was found to be the most abundant species (35.06 ± 7.01 (SE)/km²), followed by Rhesus Macaque 22.94 ± 9.45 (SE)/km². Chital density was found to be the highest (3.77 ± 0.96 (SE)/km²) among the ungulates and it was followed by Wild Boar (2.30.1 ± 0.46 SE/km²), Barking Deer (1.86 ± 0.33 SE/ km²), and Nilgai (0.53 ± 0.18 SE/ km²) (Table 2).

Food habits

In BWS, nine different prey items were identified from the collected leopard scats (n=100). No new prey species were found after analyzing 50–60 scats, as shown by diet stabilization curve (Figure 2A). The relationship between contributions of all nine prey species in the diet of leopards showed that minimum of 50–60 scats should be analyzed annually to understand the food habits of leopard, and the sample size (n=100) in the present study was adequate (Figure 3A). Among all the prey species, langur contributed the most (43.65%) to the diet of leopard whereas wild ungulates contributed only 29.35% and separately livestock contributed 6.34% of the total consumption. In BWS, presence of Sambar and

Table 1. Density, cluster size and group encounter rate of different prey species in Bhoramdeo Wildlife Sanctuary, Chhattisgarh (2016–2017).

Species	Number of sightings	Cluster size		Density (per km²)		Biomass (kg/ per km²)
		Mean	SE	Density	SE	
Chital	25	10.84	2.08	12.86	5.85	578.70
Sambar	8	2.13	0.30	0.95	0.48	123.5
Nilgai	17	3.29	0.50	5.82	2.53	855.54
Wild Boar	17	5.71	1.20	7.10	2.90	319.5
Barking Deer	41	1.70	0.15	5.74	1.30	143.5
Common Langur	25	12.52	1.23	21.82	5.34	218.2
Rhesus Macaque	17	13.588	2.02	24.03	7.34	185.03
Hare	9	1.11	0.11	1.04	0.48	2.80
Peafowl	20	3.15	0.34	6.55	2.65	22.27

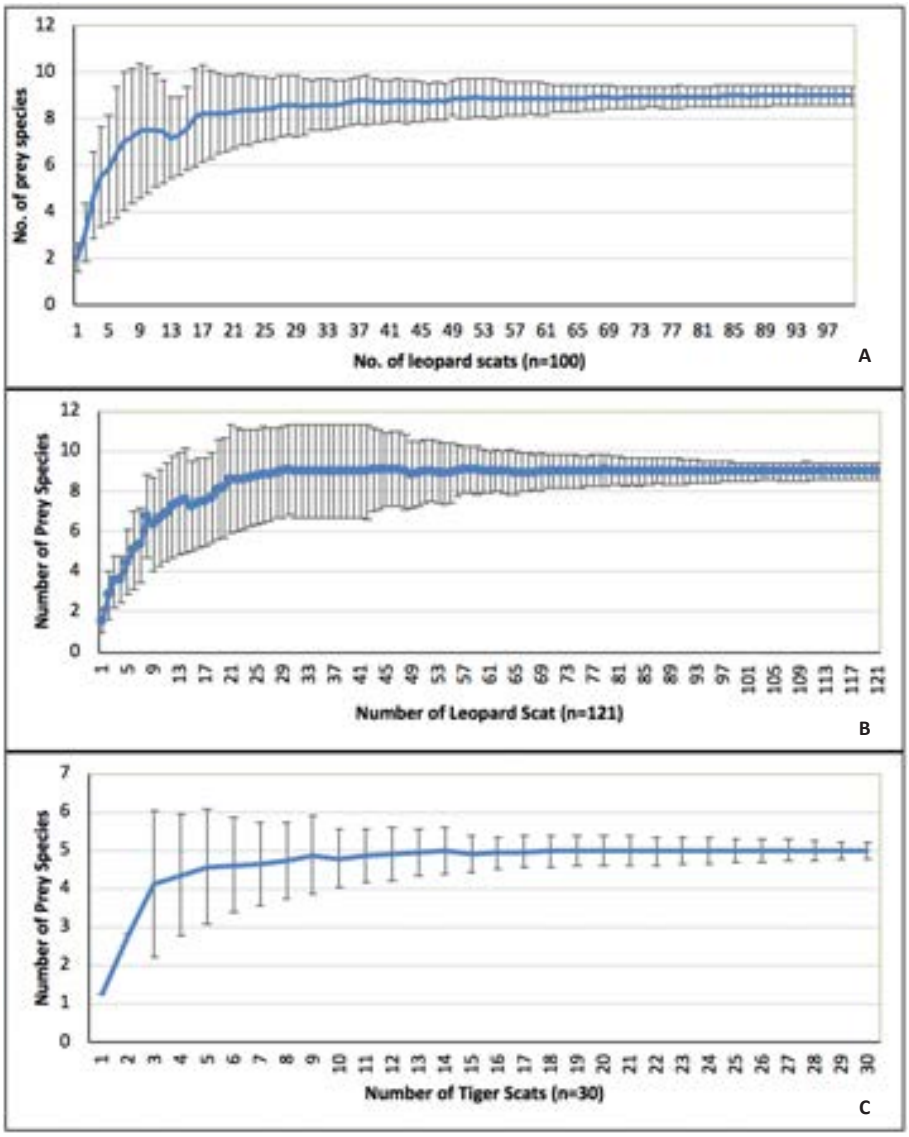

Figure 2. Diet stabilization curve of A—Leopard in Bhoramdeo Wildlife Sanctuary | B—Leopard in Udanti-Sitanadi Tiger Reserve | C—Tiger in Udanti-Sitanadi Tiger Reserve.

Four-horned Antelope were recorded but were never represented in leopard scats. Hare and other rodents were found to contribute frequently (11.9%, 7.14%) to the leopard diet (Table 3) but porcupine was found negligible, found only in the 1.58% of all leopard scat. All the wild ungulates together represented 42.89% of total biomass consumption by leopard whereas langur alone contributed the highest at 43%. Livestock represented 9.93% of the consumed biomass by leopard which was higher than the contributions made by any other wild ungulates in BWS (Table 3). Ivlev's index of prey selection criterion indicated Chital, Wild Boar and Nilgai were not significantly utilized as per their availability. Whereas Barking Deer, Indian Hare and Common Langur were the selected prey species by leopard (Figure 4) in the area.

Similarly, in the diet of leopard in USTR, nine prey

Table 2. Density, cluster size and group encounter rate of different prey species in Udanti-Sitanadi Tiger Reserve, Chhattisgarh (2016–2017).

Species	Number of sightings	Cluster size		Density (per km²)		Biomass (kg/per km²)
		Mean	SE	Density	SE	
Chital	41	3.13	0.30	3.77	0.96	169.65
Sambar	10	-	-	-	-	-
Nilgai	21	2.22	0.37	0.53	0.18	77.91
Wild Boar	36	3.23	0.33	2.30	0.46	103.5
Barking Deer	67	1.16	0.44	1.86	0.33	46.5
Common Langur	88	18.45	1.92	35.06	7.51	350.6
Rhesus Macaque	43	18.15	2.92	22.94	9.45	121.582

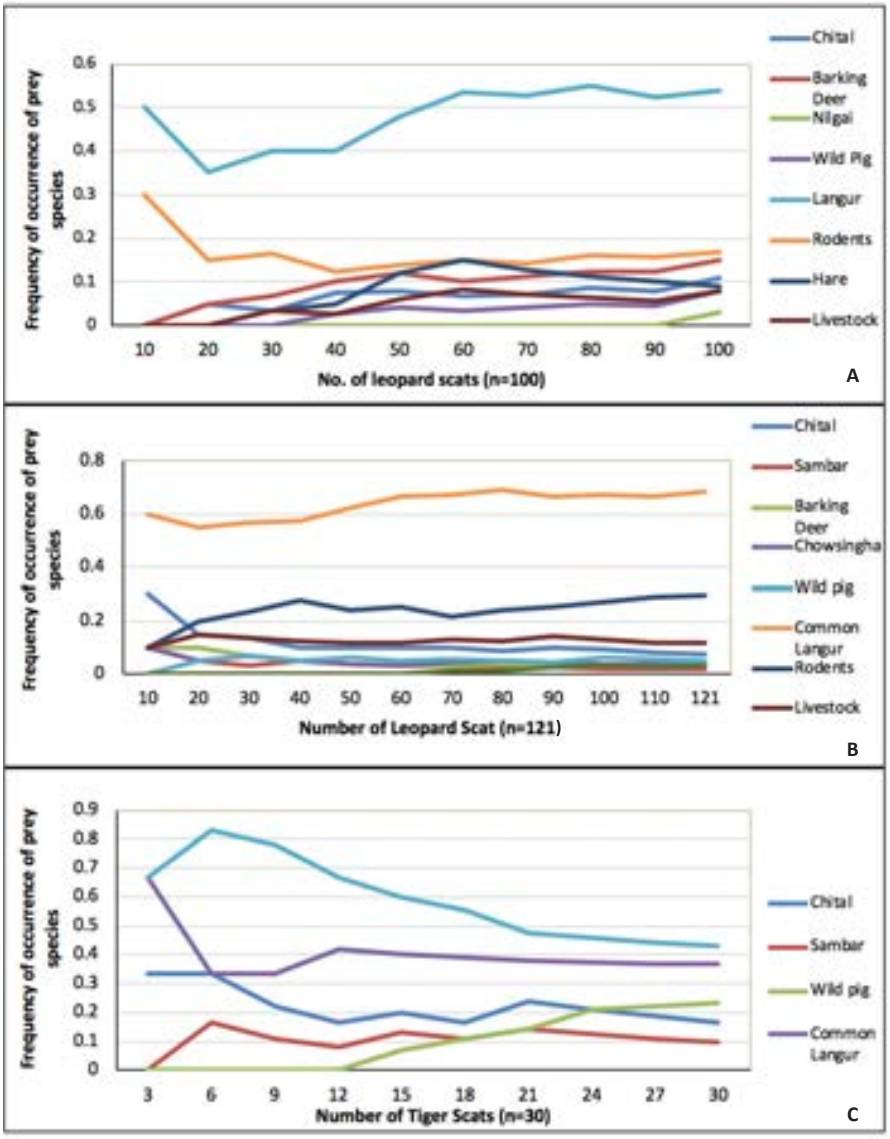

Figure 3. Relationship between contributions of prey species in the diet of A—Leopard in Bhoramdeo Wildlife Sanctuary | B—Leopard in Udanti-Sitanadi Tiger Reserve | C—Tiger in Udanti-Sitanadi Tiger Reserve.

items were identified from the scats (n=121). It was also found that after analyzing 40–50 scats, no new species were identified (Figure 2B) and from the relationship between contributions of nine prey species in the diet of leopard in Udanti Sitanadi Wildlife Sanctuary, it was understood that analysis of more than 50 scats is enough to understand the food habits of leopards (Figure 3B). Among all the prey species, Common Langur contributed maximum (50.92%) to the diet of leopard followed by rodents, livestock, Chital, Wild Boar, Barking Deer, Four-horned Antelope, sambar and birds (Table 4). Common Langur was found to be contributing maximum (57.79%) in leopard's diet in terms of biomass consumption. All the wild ungulates together contributed 26.71% of total biomass consumed by leopards, whereas livestock alone contributed 15.50% (Table 4). Ivlev's selection index indicated only Common Langur as a selected species by leopard in USTR and all other species were utilized less than their availability in the sampling area of USTR (Figure 5).

Five different prey items were identified in the diet of tiger as analyzed through scats (n=30) in USTR. After analyzing 20 scats, no new prey species was found in tiger's diet (figure 2C and 3C), that signifies our sample size was adequate to understand tiger's diet. It was found that 47.37% of tiger's diet was contributed by wild ungulates, 39.47% by livestock and 13.16% by common langur in terms of percentage frequency of occurrence (table 5). Livestock, however, contributed 47.33 % of the total biomass consumed by tiger in USTR (table 5). Ivlev's selection index expectedly indicated that tiger selected Chital and Wild Boar significantly ($p > 0.05$)

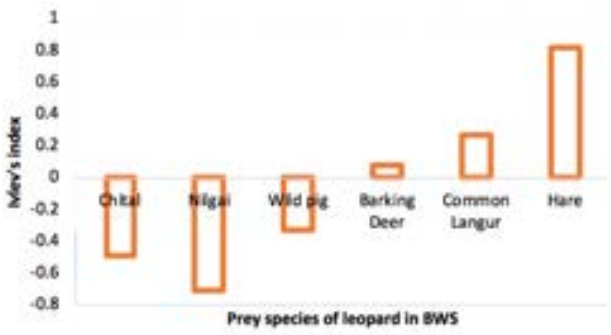

Figure 4. Prey selection of leopard as evidenced from Ivlev's Index in Bhoramdeo Wildlife Sanctuary, Chhattisgarh (2016–2017).

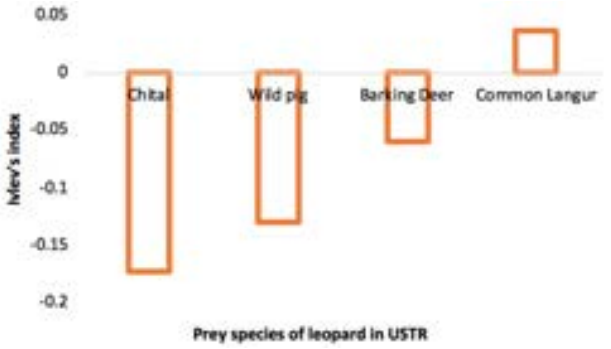

Figure 5. Prey selection of leopard as evidenced from Ivlev's Index in Udanti-Sitanadi Tiger Reserve, Chhattisgarh (2016–2017).

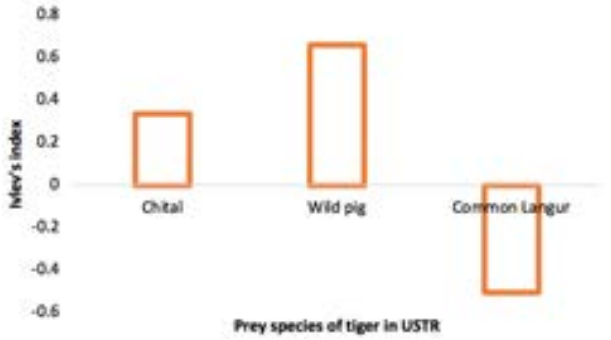

Figure 6. Prey selection of tiger as evidenced from Ivlev's Index in Udanti-Sitanadi Tiger Reserve, Chhattisgarh (2016–2017).

whereas langur was highly avoided by tiger during the study period (Figure 6). Sambar was found only two times in scat despite their low availability in the study area.

DISCUSSION

Population density of prey species, specifically ungulates were found significantly low in both the study areas BWS and USTR. Primates including Rhesus Macaque (24.03/km^2 and 22.94/km^2 in BWS and USTR, respectively) and Common Langur (21.82/km^2 and 35.06/km^2 in BWS and USTR, respectively) were found to be the most abundant prey speicies which evidently supported leopard population in the areas but were not preffered by tiger. Various studies on diet ecology of tiger indicated that they mostly prefer large to medium size prey species like Sambar, Chital and Wild Boar, whereas in Chhattisgarh large to medium size prey species have been found to be less as compared to other protected areas in central India (Table 6). Despite low abundance, however, tiger was found to prey mostly upon wild prey species including Chital and Wild Boar in USTR. Leopard was found to prefer mostly small to medium sized prey species including Barking Deer and Common Langur in both the study areas.

It can be assumed that low abundances of small to large sized wild ungulates in both the study areas have triggered livestock utilization by the large cats (Table 3-5). In USTR, livestock contributed 50% of overall biomass consumed by tiger and 15% in case of leopard. Similarly, in BWS livestock contributed more than 9% of overall biomass consumed by leopard. Less abundance of wild ungulates and higher utilization of livestock by tiger and leopard eventually have indicated that both the protected areas were not in a condition to sustain healthy large predator populations and the conditions appeared to be challenging for future large carnivore conservation efforts.

The study areas have resident populations of hunting human communities like Baiga, Kamar and Bhunjiya who still practice traditional hunting in these areas of Chhattisgarh. USTR even has pressures from external hunters who illegaly exploit the region as their hunting ground. These uncontrolled practices are serious threats to the wild ungulate populations and consequently affecting the food resources of carnivore populations in the study areas. Therefore, prey depletion by these illegal hunting practices compels large mammalian predators to prey upon livestock, which brings forward even bigger conservation threat, i.e., negative human-wildlife (tiger/leopard) interaction. Athreya et al. (2016) also supported the fact that in the situations where large prey availibility is less, chances of livestock predation is automatically elevated.

Both the study areas have villages inside the core

Table 3. Percentage frequency of occurrence, percentage biomass consumption of different prey species by leopard as shown by scat analysis in Bhoramdeo Wildlife Sanctuary, Chhattisgarh (2016–2017).

Prey Species	Presence in number of scats	% Frequency of occurrence	Average body weight	Prey consumed per field collectible scat (kg)	% Biomass (kg/per km²) consumed
Chital	11	8.73	45	1.92	13.26
Nilgai	3	2.38	147	1.98	3.73
Wild Boar	8	6.34	45	1.92	9.63
Barking Deer	15	11.9	25	1.73	16.27
Common Langur	55	43.65	10	1.25	43.00
Hare	9	7.14	2.7	0.74	4.20
Porcupine	2	1.58	-	-	-
Livestock	8	6.34	130	1.98	9.93
Rodents	15	11.9	-	-	-

Table 4. Percentage frequency of occurrence, percentage biomass consumption of different prey species by leopard as shown by scat analysis in Udanti-Sitanadi Tiger Reserve, Chhattisgarh (2016–2017).

Prey Species	Presence in number of scats	% Frequency of occurrence	Average body weight	Prey consumed per field collectible scat (kg)	% Biomass (kg/per km²) consumed
Chital	9	5.52	45	1.92	10.60
Sambar	2	1.23	130	1.98	2.44
Wild Boar	6	3.68	38	1.92	7.06
Barking Deer	5	3.07	24	1.72	5.31
Four-horned Antelope	4	2.45	19	1.59	3.90
Common Langur	83	50.92	14	1.25	63.42
Livestock	14	8.59	130	1.98	17.01
Rodents	36	22.09	-	-	-
Birds	4	2.45	-	-	-

Table 5. Percentage frequency of occurrence, percentage biomass consumption of different prey species by tiger as shown by scat analysis in Udanti-Sitanadi Tiger Reserve, Chhattisgarh (2016–2017).

Prey species	Presence in number of scats	% Frequency of occurrence	Average body weight	Prey consumed per field collectible scat (kg)	% Biomass (kg/per km²) consumed
Chital	6	15.79	45	4.32	14.63
Sambar	3	7.9	125	5.72	9.47
Wild Boar	9	23.68	45	4.05	21.94
Common Langur	5	13.16	10	2.43	6.63
Livestock	15	39.47	130	5.72	47.33

Table 6. Comparative account of prey densities from different protected areas of central India.

Area	Spotted deer		Sambar		Wild Boar		Barking Deer		Nilgai		Gaur		Chousingha	
	D	SE	D	SE	D	SE	D	SE	D	SE	D	SE	D	SE
Melghat[a]	NA	NA	10.5	3.5	NA	NA	2.7	0.3	NA	NA	5.8	1.7	NA	NA
Panna[b]	5	1.8	8.7	2.2	7.5	4	0	0	9.5	1.9	0	0	4.2	1.2
Phen[c]	0.96	0.53	6.09	2.08	20.05	5.88	2.97	0.6	0	0	2.49	1.33	0.59	0.59
Kanha[d]	26.3	3.3	8.2	0.9	4.9	0.4	2.5	0.2	0.5	0.2	4.5	1.1	NA	NA
Achanakmar[e]	10.33	2.68	NA	NA	12.72	4.31	0.97	0.35	NA	NA	8.59	3.38	NA	NA
Udanti-Sitanadi*	3.77	0.96	NA	NA	2.3	0.46	1.86	0.33	0.53	0.18	NA	NA	NA	NA
Bhoramdeo*	12.86	5.85	0.95	0.48	7.1	2.9	5.74	1.3	5.82	2.83	NA	NA	NA	NA

D—Density | SE—Standard Error | *—Study areas where the recent researches were conducted | ([a] Narasimmarajan et al. 2014, [b] Ramesh et al. 2013, [c] Jena et al. 2014, [d] Krishnamurthy et al. 2016, [e] Mandal et al. 2017).

areas and eventually have thousands of livestock which roam mostly unguarded within the protected areas and become easy prey to large predators. BWS has 29 villages inside the protected area boundary with approximately 4,000 domestic and feral cattle population, whereas, USTR has settlements of 99 villages with 26,689 livestock population. In the eight ranges of USTR, livestock density varied from 4.776–33.581/km^2 even overall density of livestock was 14.489/km^2 for the entire USTR which was found higher than the any wild ungulate population in this area. Consequently, cattle killing by both tiger and leopard has become common in these areas and may provoke severe negative human-carnivore interactions situations in both the protected areas in the near future.

The present study indicates the urgency of wild ungulate population recovery programs in both BWS and USTR and also supports to initiate the framework of the recovery plan by finding evident facts of low wild ungulate abundances and higher livestock utilization by large predators in these areas. Earlier studies showed that increasing availability of wider variety of ungulate prey species and checking grazing activities in a protected forest system may decrease the livestock predation by large predators in those areas and eventually decrease chances of negative human-large predator interactions (Basak et al. 2018; Sankar et al. 2009). Feasibility framework for recovery, however, is required by involving multi-step conservation friendly control measures. Village level mass sensitization to change their perception is vital to build up support for the ungulate recovery program and to maintain viable populations of large cats. Simultaneously strong protection framework is needed to safeguard the captive breeding and re-stalking of wild ungulate populations to increase sufficient prey-base for both tiger and leopard. Careful effort and strong scientific background behind the implementation of the ungulate augmentation plan can bring a fruitful result and can secure long term survival of large cats and other layer of carnivores in Bhoramdeo Wildlife Sanctuary and Udanti-Sitanadi Tiger Reserve in central India, Chhattisgarh.

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Hindi abstract: जंगलों में बड़े विडाल वंषी जीवों के लंबे समय तक बने रहने हेतु वहां के प्रे–बसे यानी षिकार की उपलब्धता एक अहम पैरामीटर होती है। इसी वजह से ऐसे क्षेत्रों में जहां जंगली षिकारी जीवों की कमी होती है पषुधन पर निर्भरता बढ़ जाती है और इससे बाघों जैसे जीव के संरक्षण में काफी दिक्कत होती है। इसीलिए ऐसे क्षेत्रों में जहां प्रे–बेस कम होता है वहां षिकारी जीवो के आहार पद्धति को समझना निष्चित तौर पर जरूरी हो जाता है। हमारा या अध्ययन मध्य भारत के कम षिकार की उपलब्धता वाले उदंती सीतानदी टाइगर रिजर्व एवं भोरमदेव अभ्यारण में किया गया जिससे वहां के षिकार और षिकारी जीवो के बीच के संबंध को समझा जा सके। हमने ट्रांजैक्ट लाइन सर्वे की मदद से अध्ययन क्षेत्र में पाए जाने वाले प्रे बेस की प्रचुरता का पता लगाया और पाया कि दोनों ही स्थानों में लंगूर (नॉर्थेर्न प्लेन्स लंगूर) और लाल मुँह वाला बन्दर (रीहस्स मेकाक) की संख्या अधिक है। मल के विष्लेशण से पता चला की कम षिकार की उपलब्धता होने के बावजूद बाघ चीतल, जंगली सूअर सहित अधिक मात्रा में पषुधन पर निर्भर रह रहे हैं (39%)। इसी प्रकार तेंदुआ के आहार में भी ज्यादातर लंगूर (43–50 %) और पषुधन (7–9 %) पाया गया है। दोनों ही अध्ययन क्षेत्रों में जंगली खुरधारी जीवो की कमी होना, बाघ और तेंदुए द्वारा लगातार पषुधन यानी मवेषी का षिकार करना इस बात की ओर से सूचित करता है कि ऐसे जंगलों में इनकी संख्या को बनाए रखना आने वाले कल में काफी मुष्किल होगा अथवा मध्य भारत में यदि बाघ और तेंदुए जैसे विडाल वंषी जीवो को बचाना है तो एक मजबूत कार्य योजना के साथ–साथ इनके रहवास और उसमें पाए जाने वाले षिकारी जीवों की संख्या को बढ़ाना अत्यंत आवष्यक है तभी हम इनके दूरगामी संरक्षण व संवर्धन को सुनिष्चित कर सकेंगे ।

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COMMUNICATION

Building walls around open wells prevent Asiatic Lion *Panthera leo persica* (Mammalia: Carnivora: Felidae) mortality in the Gir Lion Landscape, Gujarat, India

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Abstract: The Asiatic Lion population has increased in the last three decades, which now occupies a large regional spread with six or more identified satellite populations in eight districts of Gujarat. An overlap of lion habitat with human-dominated landscape elements leads to an increase in lion-human interactions in these growing satellite populations. A high rate of lion mortality has been observed in the periphery of Gir in the last decade due to falls into open dug wells. These wells have been excavated for irrigation in the agricultural landscape of Gir. About 145 wild animals including lions have died due to accidental falls into open wells in past 10 years. It has been observed that construction of parapet walls around wells in some of the peripheral areas of Gir Sanctuary have prevented this accidental mortality at very low cost. To assess the efficiency of these measures we did a survey of 20 random villages in the Gir Lion Landscape to collect data on the types of wells that cause this uncalled-for mortality. The paper explores the reasons for the lions falling into wells in the agricultural areas outside the Gir Sanctuary. The survey has shown that the corridors used by lions and in the satellite population areas are high risk sites where more parapet walls should be built on a priority basis. From the year 2007 to 2018 more than 48,000 parapet walls have already been randomly built in the periphery of the Gir Sanctuary. Out of 130 identified wells, 90 were protected with parapet wall or iron net while, 32 were without parapet wall and rest eight were with unfinished parapet wall. Providing a scheme for building more parapet walls around prioritized open wells would be an effective step towards Asiatic Lion conservation in the Gir Lion Landscape. Our survey indicates that there has been no mortality of lions in those wells where parapet walls have been built.

Keywords: Conservation, lion-human interactions, mortality, parapet wall, satellite population.

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Author details: Ms. Tithi Kagatara is a fellow at 'Youth for India fellowship'- SBI Foundation and working on the project with M S Swaminathan Foundation (MSSRF) titled 'NTFPs as a source of sustainable livelihood of tribal people of Koraput, Odisha'. Dr. Erach Bharucha has worked in wildlife and biodiversity conservation for over 40 years, has held several prestigious positions in the wildlife sector both government and non-government organisations and has many publications to his credit.

Author contribution: This study was a part of the MSc dissertation of Tithi Kagatara under guidance of Dr. Erach Bharucha. She has collected secondary data with the help of Division officials of Gujarat Forest Department and with help of local people. The primary data was collected personally by visiting the 20 villages of Gir Lion Landscape. EB conceptualized, designed the research methodology and personally supervised the work and interacted with local forest officials in the Gir landscape on the value of this study, which was requested by the forest department of Gujarat.

For **Gujarati abstract** see end of this article.

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INTRODUCTION

The population of Asiatic Lions in India saw a decline in Gir Sanctuary before 1990s (Singh 2017). Effective conservation, however, saw an increase in numbers in the last 20 odd years. This was accompanied by a dispersal of their population in more recent times. The present home-range of the Asiatic Lion has spread across eight districts of the Saurashtra region of Gujarat which is known as the Asiatic Lion Landscape or Gir Lion Landscape Gir Lion Landscape (GLL) (Kumar & Pathan 2015). The growing population is now expanding into suitable sub-optimal pockets of habitats in the agricultural landscape and in river corridors (Jhala et al. 2009; Basu et al. 2012). The patches of satellite population of Asiatic Lions are Girnar, Mitiyala, Lilia-Krankach-Savarkundala, Shetrunji-Jesor-Hippavadli, southwestern coast, and southeastern coast of southern Saurashtra (Singh 2000; Gujarat Forest Department 2015; Singh 2017) (Figure 3). As lion population in satellite areas increase, the human-lion interactions and their habitat conditions is getting altered. Falling into wells, getting hit by trains/vehicles, and accidental electrocution lead to mortality of lions and other wild animals in the surrounding cultural landscape (Banerjee & Jhala 2012). According to the statistics of the Gujarat Forest Department (GFD), 30 lions have had accidental deaths due to falling into open wells in the last 10 years. There is a great need to prevent this unnecessary mortality through tested conservation measures that should be implemented in high risk areas where lions disperse outside the protected area (PA).

In 2007, the GFD began to construct a few low-cost parapet walls around the wells for local farmers to see if the innovative measure would prevent high level of accidental mortality of lions and other wild animals. For several years, however, the GFD continued to rescue a large number of lions at very high cost. If the scheme could be shown to be effective as a preventive measure this would be of great conservation importance. Our study has indicated that parapet wall construction around wells is a possible measure to prevent lion mortality. A public-private partnership (PPP) under the eco-development program could be extended to such potentially hazardous areas. In the periphery of Gir, there are more than 30,000 wells that have been protected with parapet walls between 2007 and 2018. No careful study was done on the causes that led to these accidents in unprotected wells, nor was a comprehensive survey done on the benefits from this simple intervention.

The GFD provided INR 8,000 to build each parapet wall under the eco-development program. For an estimated 30,000 wells in the larger human dominated landscape, the total cost of parapet walls could be approximately INR 240 million (Rs. 24 crore). It is impractical and costly to build a wall around every well in the GLL by the forest department. Thus, the support of local people, GFD, Gram-Panchayats, Biodiversity Management Committees under the Biodiversity Act 2002, and CSR funds from industry, would have to be generated. It would, however, be cost effective if sites for building walls around open wells are focused on high risk areas. This should focus on lion movement corridors and the identified resident or temporary satellite populations of lions outside the Gir PA. The entire initiative would be a preventive strategy in the agricultural landscape outside the Gir Sanctuary to minimize accidental mortality.

STUDY AREA

The study area lies across the peripheral areas of the Gir Sanctuary (Figure 1), mainly to the east where satellite populations have taken residence and in the west where lion dispersal has also been recorded. The study includes 20 villages outside the Gir PA. All the 130 visited farms to study the wells were in revenue land. Direct visits to these randomly selected agricultural farms in known satellite areas and interviews with 102 farmers for data collection were undertaken in this study in the high dispersal zone of lions.

The four major districts of Gir Lion Landscape are Amreli, Junagadh, Gir-somnath, and Bhavnagar (Figure 1). The lions had already occupied the visited villages in the study area 30 years back and the seasonal rivers of the study area are frequently used as a corridors for lion movement across the landscape (Figure 2).

METHODS

Gir East and West divisions outside the Gir PA were used for data collection. Twenty villages of the GLL were randomly identified for survey in known satellite area. The primary data collection was based on questionnaire and interviews in villages that comprised 14 villages in 10km periphery of Gir Sanctuary and six villages from different known areas of satellite population of lions in GLL were selected. The survey included 120 respondents from the local farmers and other stakeholders of rural society.

Data on lion dispersal and accidental mortality in

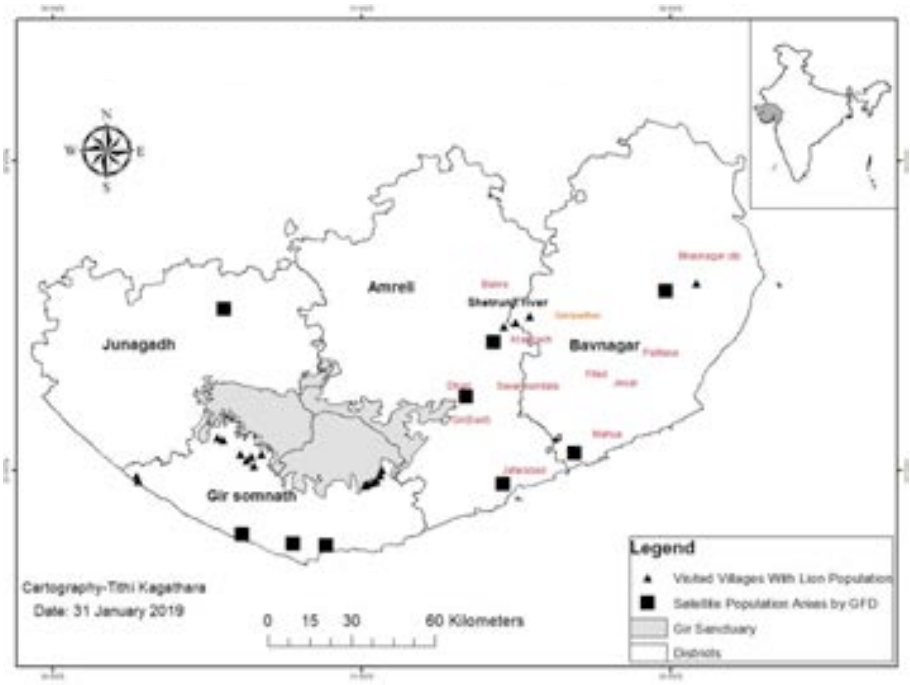

Figure 1. Study area–Gir Lion Landscape, Gujarat.

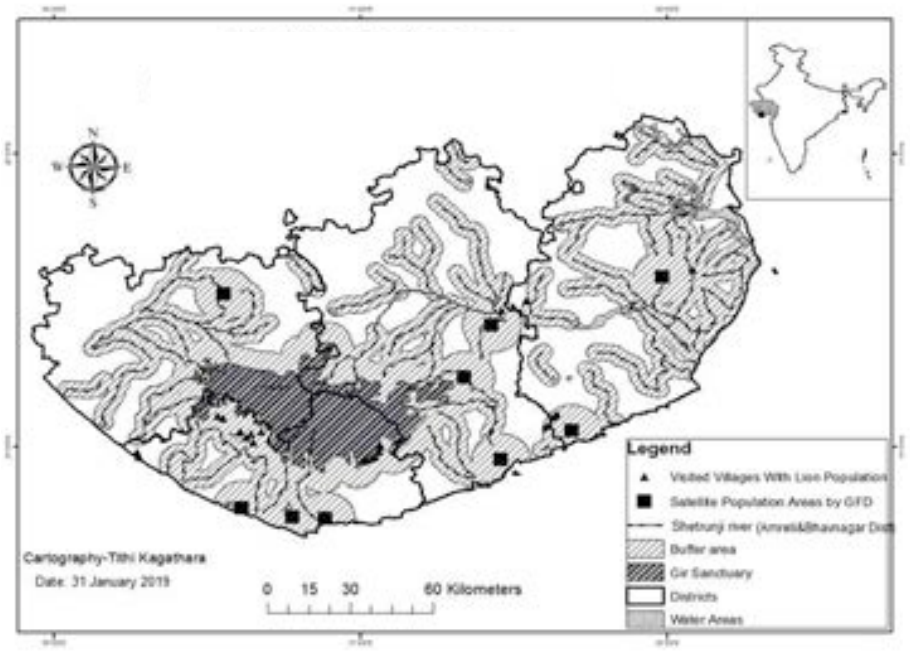

Figure 2. Prioritized buffer areas in the Gir Lion Landscape.

the study area was collected through semi-structured questionnaires with the farmers. The 130 wells in these villages were identified and studied to observe their site and local typological features. GPS reading and photo documentation of wells were done to appreciate their visibility and other features which contribute to the risk of accidental fall of the lions. The data on the number of parapet walls built and the wild animal mortality due to open wells was provided by the division office of Dhari and Junagadh which are under wildlife wing of the GFD.

Interviews of local stakeholders

The survey was conducted in all randomly selected 20 villages. The semi-structured interviews of local people in the villages ascertained people's views on the presence of lions and the reasons that they could

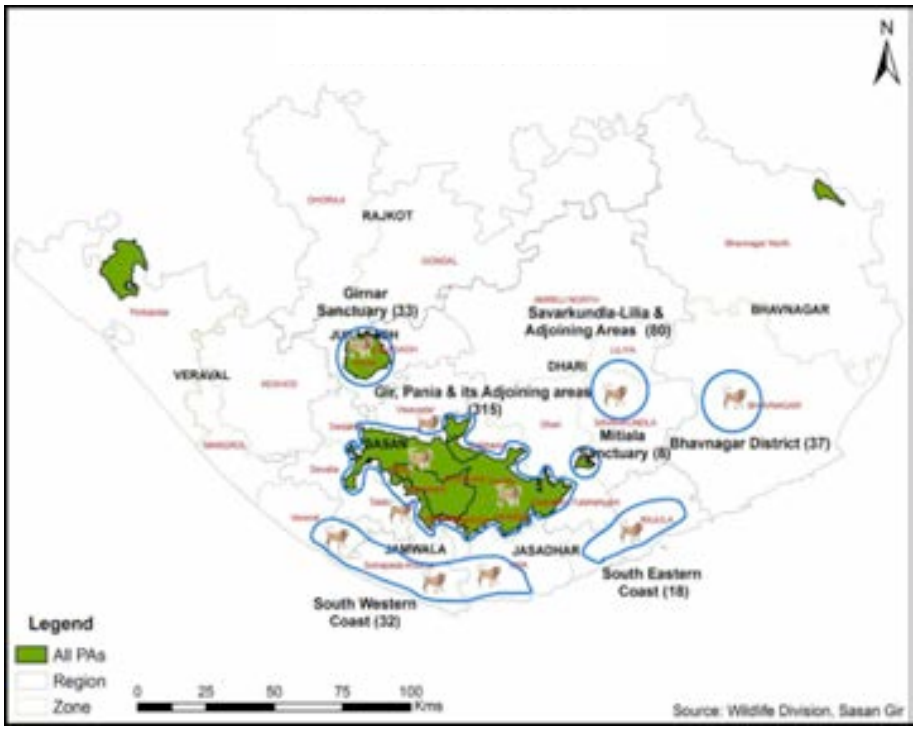

Figure 3. Habitat map of satellite population of Asiatic Lions.

Table 1. Relevant questions for assessing the parapet efficiency (number of respondents = 130).

	Indicator questions	Answers	
1	Why are lions falling into open well?	Chasing after prey (90%)	Do not know the answer (10%)
2	What is the land use where a majority of the wells are situated?	Agricultural farm land (98%)	Inside forest (2%)
3	After building a wall, were there any incidences of lions or other wild animals falling into wells?	No (95%)	Do not know the answer (5%)
4	Do you think more parapet walls would help to protect the lions?	Yes (95%)	Answer was not given (5%)

attribute for lions falling into the wells (Table 1). Snowball technique was used for choosing respondents in each village. A minimum number of five respondents and a maximum of 15 stakeholders were interviewed per village in high risk areas. Questions related to the success of the scheme through which parapet walls were built, the typology of wells, the lion presence and frequency of occurrence of prey species was documented. The views of respondents on how and why lions fall into wells was documented through a citizen science approach, as they were conversant with lion behavior over a long period of time.

The views of respondents on how the mortality occurs was also done through open ended informal interactions along with the brief questionnaire, which provided qualitative opinions that revealed that the people have clear views on their observations of lions that have fallen into wells in their area.

Field observation of well typology

The wells in agricultural lands which were visited were photographed and classified into specific risk related typologies. The typology has different implications for lion mortality prevention.

Well typology: classification and analysis

The types of wells were classified on the visual and photographic appearance documented during these field visits. A total of 130 photographs of wells were taken with their GPS locations. The vegetation and accessibility of the surroundings of the wells were documented to identify possible causes of lion mortality in the open wells. The parapet walls around wells were either square or circular with an average height of one meter. Of the 130 wells 29 were covered with concrete or wire mesh. There were 32 open wells, of these 24 were surrounded by thick growth of plants and were thus obscured from view.

According to the well typology (Figure 4), out of the 130 wells 90 were protected wells, 32 were unprotected open wells and eight were inadequately maintained and classified as others. The 90 protected wells are surrounded by one-meter high parapet walls or covered with different materials like a cement slab, nylon or iron net, which are included in the protected wells category. Parapet walls have been built around 61 wells observed in the survey. The 32 unprotected or open wells do not have any protective cover around the well. There is a high possibility of a wild animal including the lions falling into these wells. In these 32 wells, 24 were difficult to see as they were heavily surrounded by shrubs, grasses, herbs and trees which hide the well from view. There were eight wells which could be identified from a far distance (about seven meter) which are categorized as noticeable open wells. There were eight wells with one side open while the other three sides were surrounded by a parapet wall that means the walls were damaged, so are categorized as "other" types of wells (Figure 4).

RESULTS

A major finding of the survey of local residents shows that they have observed that lions fall into open wells while chasing prey. This was observed by 10% of respondents who reported that accidental falls into the wells happens mostly at night. They observed that lions fall into wells particularly while chasing after blue bull or wild boar. As the visibility of wells during the night is relatively poor due to the surrounding thick vegetation there is a high possibility that the prey jumps over the well while the lion suffers a misadventure. According to farmers in the periphery of the Gir, Blue Bull and Wild Boars feed on and ruin their crops. These species also fall into the open wells during crop raiding. According to the respondents, the Blue Bull *Boselaphus tragocamelus* population has increased in the Gir in the past 10 years due to the absence of 'naar' (Gujarati: Wolf), which used to prey on the calves and effectively controlled the herbivore population. There are, however, no wolves *Canis lupus* recorded in Gir at present and the population of Blue Bull continues to increase. The Blue Bull population in agricultural land is thus an indirect reason for lion mortality resulting from falls into open wells while stalking their prey.

The periphery of the Gir PA is divided into four divisions. The construction of parapet walls around open wells has been implemented in two divisions which are Gir West and Gir East divisions. The data collection of 14 ranges of the study area is within the immediate periphery of the Gir Sanctuary. Building parapet walls around open wells has been initiated since 2007 in different ranges (Table 2). Talala Taluka has the highest number of wells with parapet walls. According to the GFD, the villages of Gir West division have more protected wells compared to Gir East.

Data on wild fauna mortality provided by the GFD was analyzed which shows that there is a high accidental mortality of lions over the past six years 2011–2017 (Figure 5). The data includes mortality of several other wild species due to open wells.

Open wells are a risk not only for lions but also other wild animals such as Leopard, wild ungulates especially Blue Bulls. Blue Bulls formed 48% of the mortality, Leopards (28%) and lions (16%) (Figure 5).

During the survey 90% of the farmers have reported that lions fall into wells while chasing Blue Bull as the ungulate can jump over the well successfully whereas the lion may not be able to do so as easily. This locally known observation has, however, not been substantiated.

The sudden increase of lion mortality due to falls into open wells after 2015 can be explained by the increase in range of the lions outside the PA into agricultural landscapes where there are a large number of open wells, and many of which are hidden by vegetation (Figures 6 & 8). After 2010, the lion population started increasing

Table 2. Number of protected wells surrounding Gir PA (2007–2017) (Data source: Gir West Division Office, Junagadh).

		Range name	Taluka name	No. of protected wells
GIR (West)	1	Jsadhar	Una	1418
	2	Dalkhaniya	Dhari	1700
	3	Tulsishyam	Una	1469
	4	Savarkundla	Savarkundla	1758
	5	Pania	Dhari	205
	6	Sarasiya	Dhari	466
GIR (East)	7	Sasan	Talala	5413
	8	Dedkdi	Mendarda	5760
	9	Babariya	Una	3579
	10	Jamvala	Kodinar	6439
	11	Visavadar	Visavadar	4649
	12	Devaliya	Maliya-hatina	3846
	13	Talala	Talala	6854
	14	Ankolvadi	Talala	5307
Total				**48863**

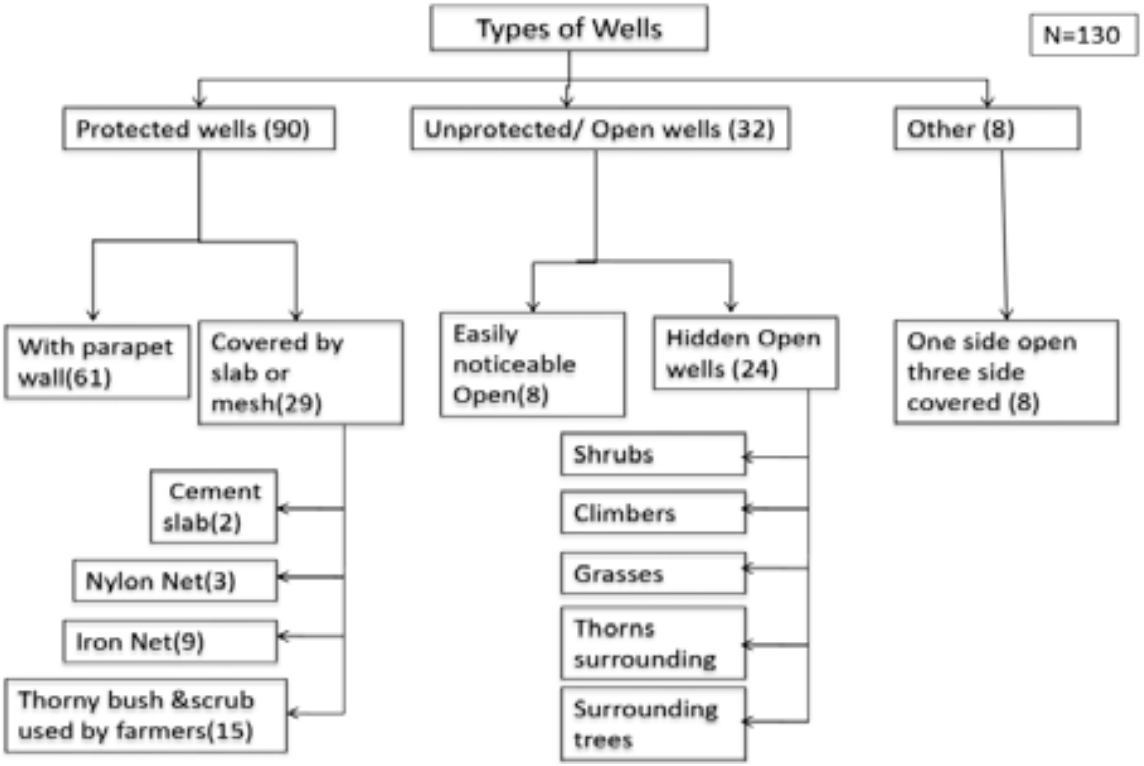

Figure 4. Types of wells (number of wells that were visited during data collection = 130).

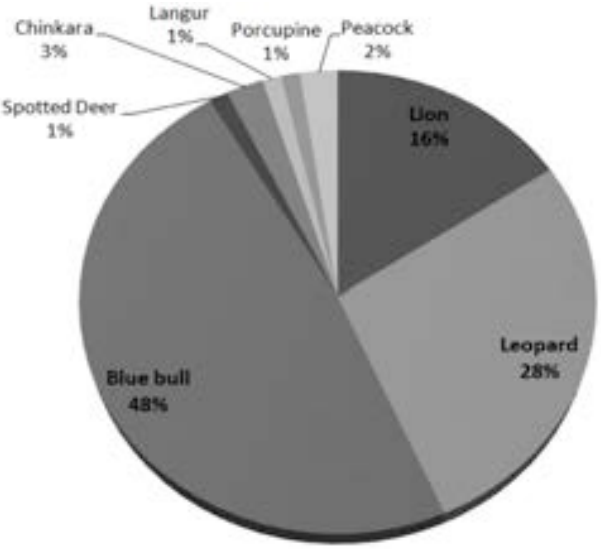

Figure 5. Wild animal mortality due to falls into wells in Gir Lion Landscape (2011–2017). (Data source: Wildlife Circle-Junagarh, Gujarat Forest Department).

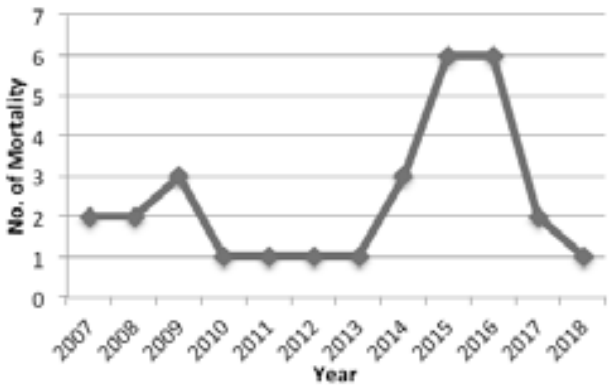

Figure 6. Lion mortality reported due to open wells around Gir Sanctuary (2007–2018).

outside the PA. In the last 25 years the number of lions inside Gir PA increased by 89 individuals or 1.3 times, while outside the PA the increase was by 150 or 9.8 times (Figure 7). Although the number of unprotected or open well in the periphery of Gir Sanctuary have decreased gradually (Figure 8), lion mortalities outside Gir PA have continued due to higher spill over of lion population out of the PA, and continued existence of unprotected live wells. The number of protected wells reflect fluctuating trend, that may be due to addition of new constructions or disintegration due to lack of maintenance. Ultimately, the number of protected wells have remained almost the same in 2016-17 as it was in 2007-8 (Figure 9).

The locations of frequent lion movements as suggested by local people during survey includes

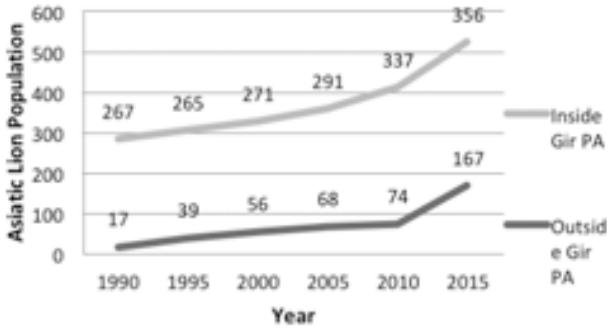

Figure 7. Asiatic Lion population inside and outside the Gir Protected Area (1995–2915).

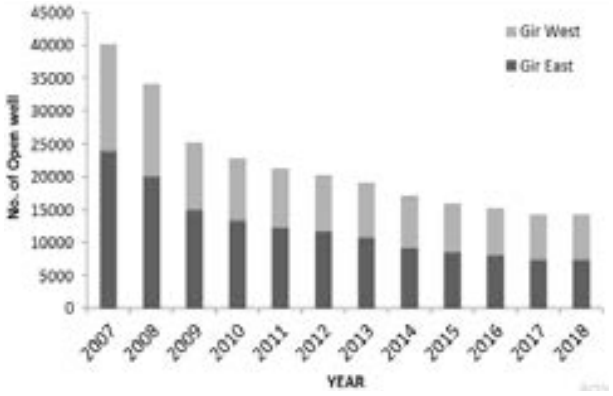

Figure 8. Unprotected or open well in the periphery of Gir Sanctuary.

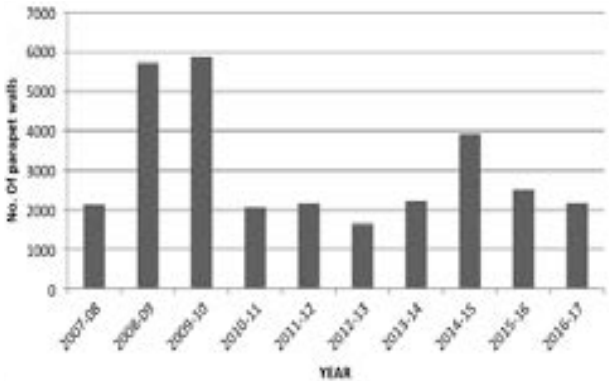

Figure 9. Number of protected wells in the periphery of Gir Sanctuary.

following areas (Figure 3):

1. Babara (Amreli) → Gagadiyo River (tributary of Shetrunji River) → Shetrunji River → Sarmda Village → Fifad (Bhavnagar) → Palitana Dam → Bhavnagar Coast
2. Gir East border → Dhai → Savar kundala → Liliya →Krankach (Greater Gir) → Gariyadhar
3. Gir (East) border → Coastal region of Rajula and Jafrabad → Mahua → Jesar (Bhavnagar) → Palitana Hills.

Local people have suggested the names of the villages and rivers which lions frequently use as movement corridors. These are potentially high-risk areas where building parapet walls would be more beneficial to limit accidental mortality.

The GLL comes under the semi-arid biogeography zone 4B- The Gujarat-Rajwara Biotic Province (Rodgers & Panwar 1988). The rivers are mainly seasonal except those inside the sanctuary. According to a recent study, lions use rivers as corridors (MoEFCC 2017). Green belts alongside the rivers are ideal isolated forest patches for the lions (MoEFCC 2017) (Basu et al. 2012). There are six known patches where satellite populations of lions are now resident (Figure 3). These are situated in agricultural land, river and tributaries, coastal areas, and foot hills in scrublands, which are concentrated in satellite populations (Meena et al. 2014).

DISCUSSION

Lions have been moving outside the sanctuary and establishing their territories (Basu et al. 2012). The fragmented suboptimal habitat patches in the matrix of cultural landscape elements where lions are frequently observed by local people is an important aspect to be recognized and managed appropriately (Dolrenry et al. 2014). The wells that have been provided with parapet walls over the years are now beginning to age. Of the 90 wells with parapet walls studied during the survey, eight require urgent repairs. As lions are moving further away from the sanctuary, the GFD needs to build parapet walls in those areas where the satellite populations have been recorded on a priority bases outside the Gir PA (Shankar 2017). A better appreciation of movement corridors, reported by local residents are other important areas for building parapets for wells.

The wells in the satellite population areas have different vegetation patterns and geographic features (Images 1–4). Even though they are situated in the overall semi-arid biogeography zone they are hidden from view by *Prosopis juliflora* and shrubs (Image 1). This is furthered due to changes in the cultural landscape which is linked to agricultural practices such as irrigation, human access, roads, and neo-urbanization (Bharucha 2017). The increasing population of Blue Bulls and invasion of *Prosopis juliflora* needs to be controlled as this hides the wells from view. The grassland of Bhavnagar (near Palitana) currently has less *Prosopis juliflora* compared to Krankach of Amreli. Controlling the spread of *Prosopis* and scrub around wells would

Image 1. Hidden open well.

Image 2. A well with the parapet wall.

Image 3. A well in a mango orchard.

Image 4. Asiatic Lion in mango orchard.

reduce the risk of accidental falls of lions into these hidden wells.

Cost analysis

The cost of building a parapet wall is about INR 8,000–10,000 according to local respondents. The GFD had helped farmers and owners of land to build parapet walls under the eco-development project after 2007. The excavation of a well costs about INR 150,000 (Rs. 1.5 lakh) depending on the site. Building a parapet wall around a well thus requires a relatively low investment to be added to the cost of the well. This amount is approximately 5% of the total cost. This must become a policy for all new wells while sanctioning wells.

Saving a lion that has fallen into a well is cost intensive, time consuming, and an important untoward event. It often requires middle term rehabilitation, or even life time care. An unnecessary preventable mortality of even a single lion is a serious biodiversity loss. People living in the cultural landscape outside the wildlife sanctuary where lions have now begun to spread spontaneously may be involved through local Biodiversity Management Committees at the Panchayat level as an outcome of the Biodiversity Act, 2002. Communication, education, and public awareness campaigns in the GLL may be initiated for lion conservation to comply with Aichi Target 1. Supporting lion conservation by building protected walls around the wells is now a proven and tested measure (Pathak & Kothari 2013). This would prevent the potential risk to lions and other wild animals from accidental mortality for one particular noticeable cause. It may also prevent accidental death of children and adults as several wells are not visible due to thick growth of vegetation around them especially during the monsoon. Steps may also be taken for keeping the surrounding of wells clear of weed growth and obstruction of visibility round the year. The removal of the obstruction from observing the edge of the wells may prevent lion mortality to some extent.

Prevention of lion mortality

Proper maintenance of wells in the agricultural landscape prevents lions and other wild animal from accidental mortality around the Gir PA. Clearing of vegetation surrounding the wells after the monsoon period to improve visibility of the wells must be done through the local Panchayat and the Biodiversity Management Committees. Removal of the obstruction from observing the edge of the wells may prevent lion mortality to some extent. Building of parapets or covering wells with a cement slab should be mandatory

in the GLL as a part of rural development. No new wells should be permitted without parapet walls or a concrete covering slab. The walls should be built during excavation of the wells itself and inspected periodically for breaches.

Rescue and rehabilitation aspects

A rescued lion loses its territory to other lions without an aggressive fight because the rescued lion has been kept in captivity before release and has lost hold over its territory. Thus, after release it is unable to take over its own territory (Kumar & Pathan 2018). This has been known to occur with both male and female lions. If a lioness has cubs and she is moved to a rescue center after falling into a well, the mortality of her cubs is likely to be high. The mortality of cubs in Gir is reported to be higher in the first six months of their life if their mother is dead. Her cubs die because of hunger. Mortality is also observed due to in-fights between the released and resident lions (Pati & Vijayan 2002). It is reported that a rehabilitated mother cannot produce milk for the cubs, if the captivity period time has been over two weeks (Singh 2000). Thus, even if lions are rescued from the wells, there are serious concerns about their rehabilitation in the wild.

CONCLUSION

Interactions with local observers have suggested that the priority to build protective parapet walls should include:

- Peripheral area of the PA for about 10km mainly in the southern fringe.
- Known movement corridors of lions which use tributaries of Shetrunji River where wells are adjacent to villages in agricultural land.
- Known pockets of satellite populations which are 40 to 100 km away from the edge of the PA such as southwestern Coast, southeastern Coast, Pania and its adjoining areas, Savarkundala-Lilia and adjoining areas, Bhavnagar District and Girnar Sanctuary to northern side of Gir.

The buffer has been identified around the Gir Sanctuary, rivers and satellite population areas of lions by the Gujarat Forest department. Ten kilometer buffer around the Gir Sanctuary as well as the satellite population areas of lions; while for the rivers, three kilometer buffer was identified with help of Arc MAP. Two kilometer buffer area around the Gir sanctuary should be prioritized for building parapet walls around wells due to frequent movement of lions (Figure 2).

Reducing the risk of mortality of an endangered species is a key to its long term survival. A simple measure to prevent mortality of the lions in Gir which has been highly successful has been to build parapet walls around open wells into which lions were frequently suffering accidental deaths. The positive attitude of local people towards the scheme of building these parapet walls has also contributed towards preventing accidental mortality of other wild fauna. This mitigation measure for addressing lion-human interaction may be prioritized in high risk areas where satellite populations of lions are present. The completeness of information on risks identified and on current movement patterns of lions across the GLL will need to be addressed with all local stakeholders and the GFD. The citizen science approaches of eliciting this information can be used to appreciate where the wells should be developed in these prioritized situations.

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Gujarati abstract: છેલ્લા ત્રણ દાયકામાં એશિયાઇ સિંહોની વસ્તીમાં વધારો થયો છે જે હવે ગુજરાતના આઠ જિલ્લાના અલગ અલગ વિસ્તારમાં વસવાટ કરે છે. ગીરમાં સિંહોનો વસવાટ મનુષ્ય સમાન હોવાથી તેઓ એકસાથે જોવા મળે છે. છેલ્લા 10 વર્ષમાં સિંહોનો મૃત્યુ આંક ખુલ્લા કુવાને લીધે ઘણો વધ્યો છે જે ગીર અભ્યારણ્યની ફરતે આવેલ છે. આ કુવાઓ ખેતીલાયક જમીનની પાણીની જરૂરિયાત માટે ખોદવામાં આવેલ છે. છેલ્લા 10 વર્ષમાં અંદાજીત 145 જંગલી પ્રાણીઓના ખુલ્લા કુવામાં પડી જવાથી મૃત્યુ નીપજ્યા છે. અધ્યયન પરથી જાણવા મળ્યુ છે કે ખુલ્લા કુવાને ફરતે પાળ/દિવાલ બાંધવાથી સિંહોના મૃત્યુદરમાં કેટલાંક અંશે ઘટાડો લાવી શકાય છે. આ સંભાવના ચકાસવા માટે અમે ગીર અભ્યારણ્યની આસપાસ આવેલ 20 ગામોમાં રેન્ડમલી સરવે કર્યો હતો અને આ પેપરમાં સિંહોના ખુલ્લા કુવામાં પડવાના કારણો પર ચર્ચા કરી છે. સરવે પરથી જાણવા મળ્યુ છે કે લાયન કોરીડોર અને સેટેલાઇટ પોપ્યુલેશન વિસ્તારોમાં સૌ પ્રથમ કુવા ફરતે પાળ બનાવવી જોઇએ. ગીર લાયન લેન્ડસ્કેપમાં 2007 થી 2018 સુધીમાં અંદાજીત 48000 કુવાઓને ફરતે દિવાલ બનાવાઇ છે. ડોક્યુમેન્ટેશન કરેલા કુલ 130 કુવાઓમાંથી 90 કુવાઓમાં દિવાલ હતી અને 32 કુવામાં કોઇપણ પ્રકારની દિવાલ ન હતી બાકીના 8 કુવાઓની દિવાલ અધુરી બનાવેલ હતી. " ખુલ્લા કુવા ફરતે દિવાલ બનાવી" યોજના અંતર્ગત જો પ્રાયોરીટાઇઝ્ડ વિસ્તારોમાં અમલ કરવામાં આવે તો એ સિંહોના સંરક્ષણ માટે ખુબ જ મહત્વની સાબિત થાય. અમારા સરવે મુજબ કોઇ સિંહનુ મૃત્યુ એવા વિસ્તારમાં નથી થયુ જ્યાં કુવા ફરતે દિવાલ બનાવેલ છે.

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COMMUNICATION

Taxonomic and ecological notes on some poorly known bats (Mammalia: Chiroptera) from Meghalaya, India

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Abstract: The chiropteran diversity of Meghalaya State is very high with 65 reported species. Taxonomic and ecological information on many of these bat species, however, are scant or largely outdated. We reinforce the records on five poorly known bat species in Meghalaya, viz., *Megaerops niphanae*, *Myotis pilosus*, *Kerivoula kachinensis*, *Miniopterus magnater*, & *Miniopterus pusillus*, critically evaluate their taxonomic assignment, and provide detailed morphometric data for further comparisons. For three of these species, we also provide echolocation call data that are reported for the first time in India. Together, these new data highlight the need for a more robust and critical examination of the rich bat fauna existing in the foothills of the Himalaya.

Keywords: Biometrics, Chiroptera, echolocation call.

Abbreviations: ZSIS—Collections of the Zoological Surveys of India, Shillong | Fhi—highest frequency (in kHz) | Flo—lowest frequency (in kHz) | FmaxE—frequency of maximum energy (in kHz).

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Competing interests: The authors declare no competing interests.

Ethics statement: All animals were handled according to the recommendation of the American Society for Mammalogy. Since bats are not legally protected in India (except for two species which are outside the purview of the present study) and our sampling sites were located outside protected areas, no approval from the state forest department was necessary for specimen collection. We, however, sought verbal approval from the local authorities to conduct this research and collection of vouchers

Author details: Uttam Saikia is working as Scientist-C in Zoological Survey of India, Shillong and is interested in the systematics of the bat fauna of India with special reference to northeastern India. Adora Thabah studied the diversity and ecology of bats in Meghalaya for her PhD thesis. She has worked as a freelance ecologist and now continues to survey these mammals and tries to develop action plan to protect them. Manuel Ruedi is interested in the systematics position and biogeographic origin of bats from the Old World. He uses a combination of morphological and molecular approaches to reconstruct their evolution.

Author contribution: US, MR and AT conducted the field surveys, recorded the calls and identified the specimens. MR analyzed the ultrasounds. US and MR wrote the manuscript.

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INTRODUCTION

A variety of factors like geological age, past and present climatic conditions or unique biogeographic history have shaped the present faunal composition of northeastern India (Pawar et al. 2007). The Meghalaya subtropical forest ecoregion covering the state of Meghalaya and the adjacent areas of Assam is recognized as one of the most species-diverse area in the Indomalayan region (Wikramanayake et al. 2002) with more than 165 species of mammals (Rodgers & Panwar 1988; Das et al. 1995; Saikia et al. 2018); and a total of 162 species of mammals in Meghalaya State (Lyngdoh et al. 2019). Meghalaya harbours numerous caves of which nearly a thousand have been scientifically explored and mapped during the "Caving in the Abode of the Clouds" project (Prokop & Arbenz 2015). Caves serve as a major roosting place for many bat species since they offer a relatively stable microclimate, protect them from unfavourable environmental conditions and reduce predatory pressure (Kunz 1982). Availability of suitable roosts is a critical factor that largely determines diversity and distribution of bats (Kunz 1982; Arita 1993). Thus, the state with abundant caves especially in the limestone belt offers plentiful roosting opportunities for cave roosting bats. Indeed, 65 species of bats have been recorded so far from the state, including several recent discoveries resulting from explorations conducted during the above-mentioned caving project (Ruedi et al. 2012a,b; Saikia et al. 2017, 2018; Thong et al. 2018). Some older records from the state pertain to exceptionally rare species, such as *Eptesicus tatei* or *E. pachyotis* which have hardly been reported again in India since their discovery (Bates & Harrison 1997; Mandal et al. 2000), and several additions to the list emerged from a critical re-examination of vouchered specimens of apparently widespread taxa, such as those in the *Murina cyclotis* group (Ruedi et al. 2012a). Other additions such as *Tylonycteris fulvida* or *T. malayana* (Tu et al. 2017), or *Hypsugo joffrei* (Saikia et al. 2017) emerged from a recent update of their former taxonomic assignation, but a number of other species were only mentioned in diverse reports, without proper taxonomic or biometric description (Ruedi et al. 2012b; Saikia 2018; Saikia et al. 2018). This underscores the need for further data in a number of poorly known bats of Meghalaya with scant information on taxonomy, distribution and ecology. Such information is particularly important in the context of the continued degradation of natural ecosystems in Meghalaya (Sarma & Barik 2011; Swer & Singh 2013). In this communication, we present biometric information for *Megaerops niphanae*, *Myotis pilosus*, *Kerivoula kachinensis*, *Miniopterus magnater*, and *M. pusillus* from Meghalaya and also provide for three of them, a description of their echolocation calls that will aid their further monitoring in the wild.

MATERIALS AND METHODS

Study area

The northeast Indian state of Meghalaya lies within 25.021–26.130 ^{0}N latitude and 89.830–92.802^{0}E longitude and has an area of 22,429km^{2} (Anonymous 2005). Geologically, Meghalaya mostly consists of a stable structural block called the Shillong Plateau, with a maximum height of 1,950m. A sedimentary sequence called the Jaintia group lies to the south of this plateau and is a mixture of limestone, sandstone and coal deposits (Tringham 2012). The state receives a high annual rainfall with an average of 2,689mm in the eastern parts and 7,196mm in central and western Meghalaya (Haridarshan & Rao 1985). Due to high rainfall, the rainwater absorbed into the ground reacts with the limestone and dissolves it, ultimately creating an extensive network of underground drainage systems, including caves. Such caves are developed intermittently along the whole limestone belt of the state and also in sandstone and quartzite areas of southern Meghalaya (Tringham 2012). The state has a recorded forest cover of 76.4% of the total geographic area of which 43.8% consists of very dense and moderately dense forest (Forest Survey of India 2017). The vegetation in the state can be characterised as tropical evergreen forest, tropical semi-evergreen forest, tropical moist and dry deciduous forest, subtropical pine forest, temperate forest, grasslands and savannas (Haridarshan & Rao 1985).

Field sampling

During the course of speleological explorations conducted between 2011–2018 in various parts of Meghalaya by the team of the "Caving in the Abode of the Clouds" project, we captured bats by using a two-bank harp trap or mist nets erected across presumed flight paths. These capture devices were usually placed in front of cave entrances or in the surrounding forests. Captured bats were kept individually in cotton bags, sexed, measured, preliminarily identified (following Bates & Harrison 1997) and photographed before being released in the same place. A few animals were kept for further examination as vouchered specimens.

These animals were euthanized with chloroform vapour and transferred to 70% ethanol for preservation. The preserved carcasses and prepared skulls were later deposited in the collections of the Zoological Survey of India, Shillong (ZSIS). All animals were handled according to the standards recommended by the American Society of Mammalogists (Sikes et al. 2011).

Comparative material consisting of four *Miniopterus fuliginosus* from Himachal Pradesh deposited in the collections of the Zoological Survey of India was also examined. Standard sets of external and craniodental measurements were obtained with digital callipers accurate to the nearest 0.1 and 0.01 mm, respectively. The baculum of the male specimen of *Myotis pilosus* was prepared by macerating the dissected penis in 6% KOH solution and stained with Alizarin Red S (Topal 1958). The prepared baculum was measured and photographed under a stereo zoom microscope with 40–50 x magnification and using the software Leica Application Suite, Version 3.

The acronyms for measurements are: tail length (T), ear length (E), tragus length (Tr), hindfoot length, including claw (HF c.u), forearm length (FA), tibia length (Tb), greatest length of skull including incisors (GTLi) and excluding incisors (GTL), condylobasal length (CBL), condylocanine length (CCL), maxillary toothrow length (CM^3), width across third molars (M^3M^3), width across canines (C^1C^1), zygomatic breadth (ZB), postorbital constriction (POC), breadth of braincase (BB), mastoid breadth (MAB), length of mandible including incisors (MLi) and excluding incisors (ML), mandibular toothrow length (CM_3), and coronoid height (COH). These measurements generally follow definitions by Bates & Harrison (1997).

Bioacoustics

For three of the species (*Myotis pilosus, Miniopterus magnater* and *Kerivoula kachinensis*), we recorded echolocation calls while individuals were either flying free in front of the cave just prior to capture (former two species), or while the animal was held in the hand (latter species). Recordings were done with an Anabat Walkabout bat detector (Titley Scientific, UK) working at a sampling rate of 500kHz. The calls were later analyzed on spectrograms generated with the program BatSound Pro v4.2.1 (Pettersson Elektronik, Upsala, Sweden), using a FFT hanning window size set at 1024 samples. For each call the following parameter were measured: frequency of maximum energy (FmaxE, expressed in kHz) and duration of the pulse (in ms); highest (Fhi) and lowest frequency (Flo) of the pulse (expressed in kHz); and interpulse duration (in ms). For each recording (one per species), statistics were calculated based on a sequence of 10 pulses characterized by a high signal to noise ratio.

RESULTS

Systematic account

***Megaerops niphanae* Yenbutra & Felton, 1983**
Ratanaworabhan's Fruit Bat

New material: One adult female, ZSIS-455, 17.ii.2018, Kyrshai (25.840^{0}N, 91.322^{0}E; 100m), West Khasi Hills.

Description and taxonomic notes: A relatively small species of pteropodid bat with a characteristic short and broad muzzle with slightly tubular nostrils (inset of Image 1). The ears have no white markings and the species has a very short tail. It is the largest among the four species known under the Indo-Chinese genus *Megaerops* (Mandal et al. 1993). The fur of the captured individuals was soft, greyish-brown dorso-ventrally. The ears, wings and interfemoral membranes were light brown. The small tail of about 11mm was entirely enclosed within the interfemoral membrane. The larger size (FA > 60.0mm) and the presence of a short internal tail are diagnostic characters distinguishing it from *M. ecaudatus* (Yenbutra & Felton 1983) which possibly is also distributed in the eastern parts of northeastern India (see Discussion).

Craniodental characters: The skull rises gradually to the midpoint almost in a straight line before descending sharply and in dorsal view the rostrum appears squarish in outline (Image 1). There is a wide interorbital groove and the spine-like projections come out from the orbital margins. The second upper incisor is reduced and only one incisor is present in each hemi-mandible. The upper canine is strong and curved inward. The first upper premolar is minute. Only one molar in the upper jaw and two in the lower jaw are present. Skull measurements of the female ZSIS-455 are given in Table 1 and confirm that the species is much larger than the other species in the genus *Megaerops* (e.g., GTL 29.0mm).

Ecological notes: A prepubertal female and an adult female in non-reproductive state were caught in mist nets placed in a secondary forest with bamboos in Kharkhana area of East Jaintia Hills during mid-February 2014. Both animals were photographed and released on the spot. Another female was caught in a harp trap set in the Kyrshai area, the West Khasi Hills, Meghalaya, in February 2018 and retained as a voucher specimen (ZSIS-

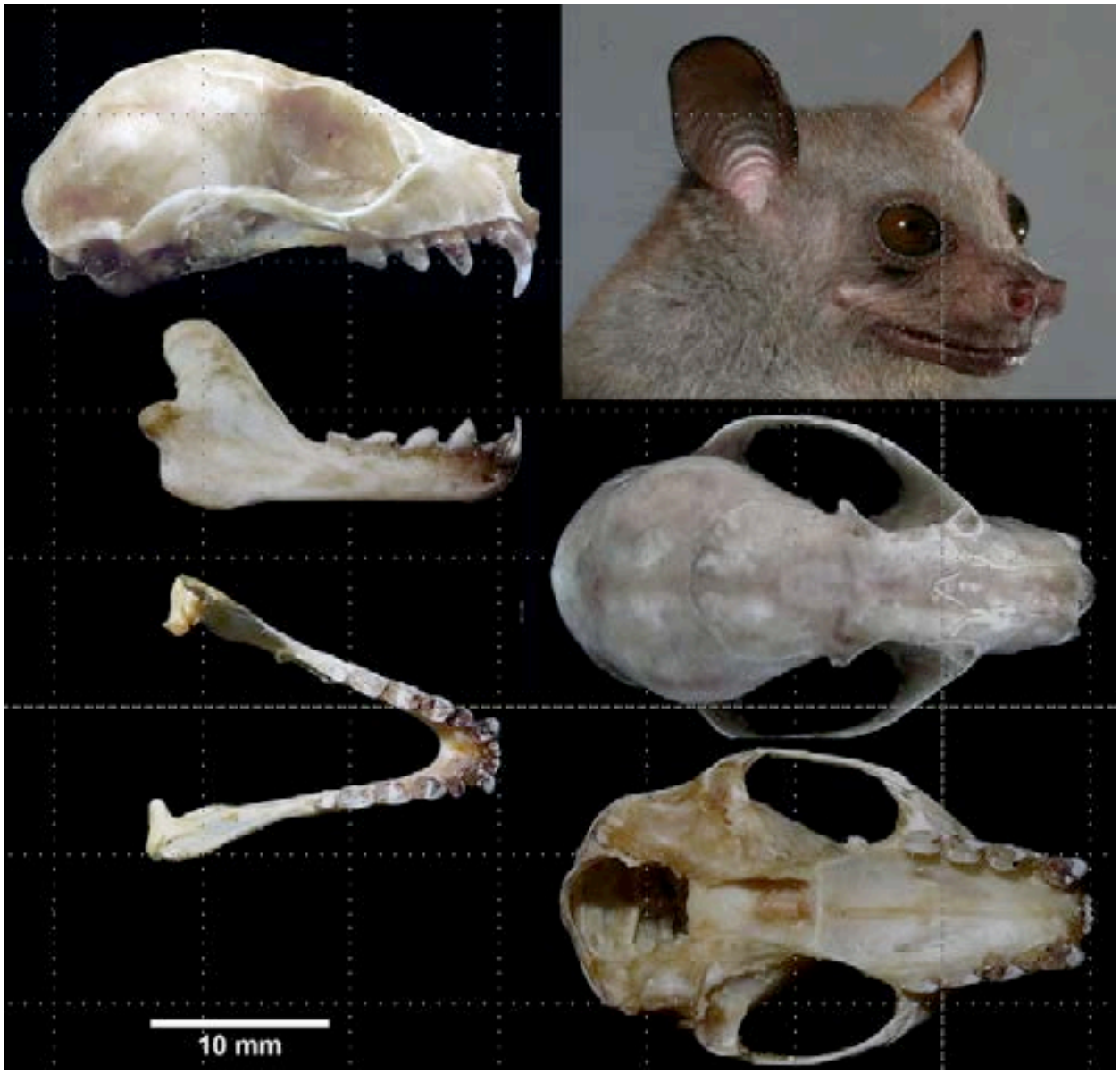

Image 1. Dorsal, ventral & lateral view of cranium and lateral & ventral view of mandible of *Megaerops niphanae* (specimen ZSIS-455). The inset illustrates a live specimen captured and released in Kharkhana, Jaintia Hills, Meghalaya. © U. Saikia & M. Ruedi (inset).

455). The animal was caught in the vicinity of a village and other bats, presumably from the same species were seen feeding on a fig tree *Ficus racemosa* on the bank of river Khri (Kulsi). The village is surrounded by mixed deciduous forests. The Kyrshai specimen did not show any apparent sign of pregnancy or lactation. In Thailand, this species is found at 140–240 m in a variety of habitats including pristine tropical forest and farmland adjacent to forests (Bates et al. 2008b). In Bangladesh, this bat was recorded in an orchard in a heavily urbanized area (Islam et al. 2015).

***Myotis pilosus* (Peters, 1869)**

Rickett's Big-footed Myotis

New material: One male, 28.ii.2015, ZSIS-396, Phlang Karuh Cave (25.188^{0}N, 91.618^{0}E; 80m), Shella, East Khasi Hills; one male and one female, 17.ii.2018, ZSIS-480, 481, Krem Dam (25.297^{0}N, 91.584^{0}E; 545m), Mawsynram, East Khasi Hills.

Description and taxonomic notes: This is one of the largest species of *Myotis,* the average forearm length of the examined Indian specimen was 53.4mm (51.1–54.3 mm; Table 2). The dorsal side is light brown, the ventral greyish. The membranes are dark brown with lighter

Table 1. External and craniodental measurements of *Megaerops niphanae* from northeastern India and Bangladesh. The legend of abbreviations can be found in the Material and Methods section. For external measurements of the Meghalaya individuals, we report data from three females (two released), while the skull measurements pertain to single female specimen ZSIS-455.

Measurements (in mm)	Meghalaya (present study)	Manipur (Mandal et al. 1993)	Mizoram (Mandal et al. 1997)	Arunachal P. (Das 2003)	Bangladesh (Islam et al. 2015)
TL	11	-	-	-	-
E	18.4–19.5	17.5–19.2	17.2–18.5	14.7–20.1	16.0
FA	60.0–64.2	59–59.4	58.0–62.3	54.0–64.6	58.3
TB	24.2–25.9	22.3–27	23–25.7	20.9–27.2	23.9
HF (c.u.)	14.2–14.8	14.0	12.0–13.7	11.0–14.0	10.6
GTL	29.0	26.3–28.0	27.9–28.7	26.6–29.7	28.4
GTLi	29.1	-	-	-	-
CCL	26.8	-	24.4–27.1		26.5
ZB	17.7	17.6–17.8	17.7–18.8	16.3–19.5	18.8
BB	12.9	12.4	12.0–12.3	11.6–13.1	
MAB	13.3	-	-	-	11.3
POC	5.5	5.0	5.2–6.0	4.7–5.7	
CM^3	9.8	8.3–8.6	9.1	8.0–9.5	8.7
M^3M^3	8.7	7.9–8.3	8.3–8.6	7.6–8.9	8.7
C^1C^1	6.0	5.3–5.7	5.4	3.0–5.8	5.8
M^1M^3	6.5	-	-	-	-
ML	21.0	19.0–20.0	20.4–20.9	17.7–20.2	20.9
MLi	22.0	-	-	-	-
CM_3	10.8	-	-	-	9.6
M_1M_3	6.1	-	-	-	-

interfemoral membranes (especially on the ventral side). The uropatagium is essentially naked. The muzzle is dark brown and both lips have a few whiskers, especially on the sides. The ears are relatively long with concave anterior border and convex posterior margin. The margin of the tragus is almost straight; its tip is bluntly pointed (inset of Image 2). The feet are very large (18mm) with sharp curved claws. The wing membrane attaches to the ankles slightly above the tibio-tarsal joint.

Craniodental characters: This large *Myotis* has an average skull length of 20.2mm in the examined specimens (Table 2). The skull profile is relatively flat and long (Image 2). The rostrum is broad and has a shallow depression in the middle. The nasal notch is V-shaped. The braincase elevates gradually from the rostrum and appears almost horizontal in lateral profile. The sagittal crest is scarcely visible, auditory bullae are small and zygomata are thin. Upper incisors are bicuspidate with a shorter secondary cusp. There is a gap between the posterior incisor and the canine. The length of the canine considerably exceeds the length of the third premolar. The second premolar is intruded from the toothrow. Lower molars are myotodont.

Baculum structure: The baculum of the ZSIS-480 specimen is longish with a broad base and tapers towards the tip forming a blunt cone (Image 3). The base has a prominent keel on the dorsal surface which runs for about two-third of the length of the baculum. Like other members of *Myotis*, the baculum is minute with a length of 0.77mm and a breadth at the base of 0.21mm.

Echolocation calls: Echolocation calls are typical of myotinae, brief (duration 6.9±0.5, range 6.4–7.9 ms) and frequency modulated (Figure 1). Pulses recorded in front of the cave had a sigmoidal shape, started at around 61kHz (Fhi 60.7±4.4, range 50.1–65.5 kHz), ended at around 30kHz (Flo 29.8±1.0, range 28.4–31.7 kHz), and showed a marked maximum of energy at 35kHz (FmaxE 34.9±0.7, range 34–36.2 kHz). Interpulse intervals were short (78.1±10.8, range 64–105 ms). These call characteristics are comparable to those measured by Ma et al. (2003) for Chinese exemplars of *M. pilosus*.

Ecological notes: In our study, *M. pilosus* were found to roost in caves traversed by large river systems. In

Image 2. Dorsal, ventral and lateral view of cranium and lateral and ventral view of mandible of *Myotis pilosus* (specimen ZSIS-354). The inset illustrates the live specimen captured in Phlang Karu Cave, East Khasi Hills, Meghalaya. © U. Saikia & M. Ruedi (inset).

Krem Dam (near Mawsynram, East Khasi Hills) a small colony of this bat was present but the roost itself could not be seen, as it was located deep within the crevices of the cave ceiling, in the upper level of the cave passage. These bats were observed at dusk to be trawling over the calm waters flowing within the cave. Dietary analysis of *M. pilosus* from this cave revealed that fish constituted a significant portion of its diet in the drier months from December to March (Thabah 2006). Very little bat activity was noted in the same cave in February while the temperature dropped below 10^0C.

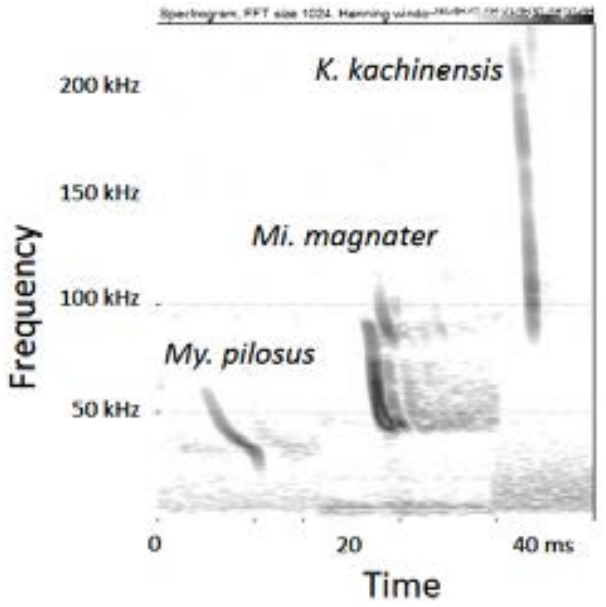

Figure 1. Spectrograms of echolocation calls of *Myotis pilosus*, *Miniopterus magnater*, and *Kerivoula kachinensis* recorded in Meghalaya and visualized with the program BatSound. These bats were recorded while flying near cave entrances or while hand-held (for *K. kachinensis*).

Image 3. Dorsal profile of the baculum of *Myotis pilosus* (specimen ZSIS-480).

***Kerivoula kachinensis* Bates et al., 2004**
Kachin Woolly Bat

New material: One female, 14.ii.2018, ZSIS-454, Sakwa (25.239^{0}N, 92.692^{0}E; 1,150m), East Jaintia Hills; one female, 20.ii.2011, ZSIS-571, Laitkynsew (25.215^{0}N, 91.664^{0}E; 815m), East Khasi Hills District.

Description and taxonomic notes: It is a relatively large species of *Kerivoula* with an average forearm length of 40.8mm in Meghalayan specimens. Fur colouration is overall dark and ochraceous brown, showing little contrast between the upper and under parts. Individual hairs have light brown tips with a shiny appearance while the roots are dark brown (Image 4). Ears are broad and oval-shaped and have scattered hairs on the internal surface. The tragus is thin, long and pointed with a straight anterior margin and slightly concave posterior margin and reach almost two third of the ear length (Image 4A). Wings attach to the base of toes. In our specimens, the fifth metacarpal is the longest (44.5–46.6 mm) followed by the fourth (43.4–44.3 mm) and the third (41.4–41.6 mm), which slightly exceeds the length of forearm (40.3–41.4 mm). The second phalanx of the third metacarpal exceeds the length of first phalanx. As no male individual from India could be examined so far, these metric wing characters may not apply to both sexes, especially because several *Kerivoula* species are sexually dimorphic. An oval and whitish fleshy callosity

Image 4. Portrait (A), dorsal (B) and ventral pelage (C) of *Kerivoula kachinensis* from Laitkynsew, Meghalaya (specimen ZSIS-571). Note the ochraceous brown tips and dark brown hair roots of both dorsal and ventral hairs. © M. Ruedi.

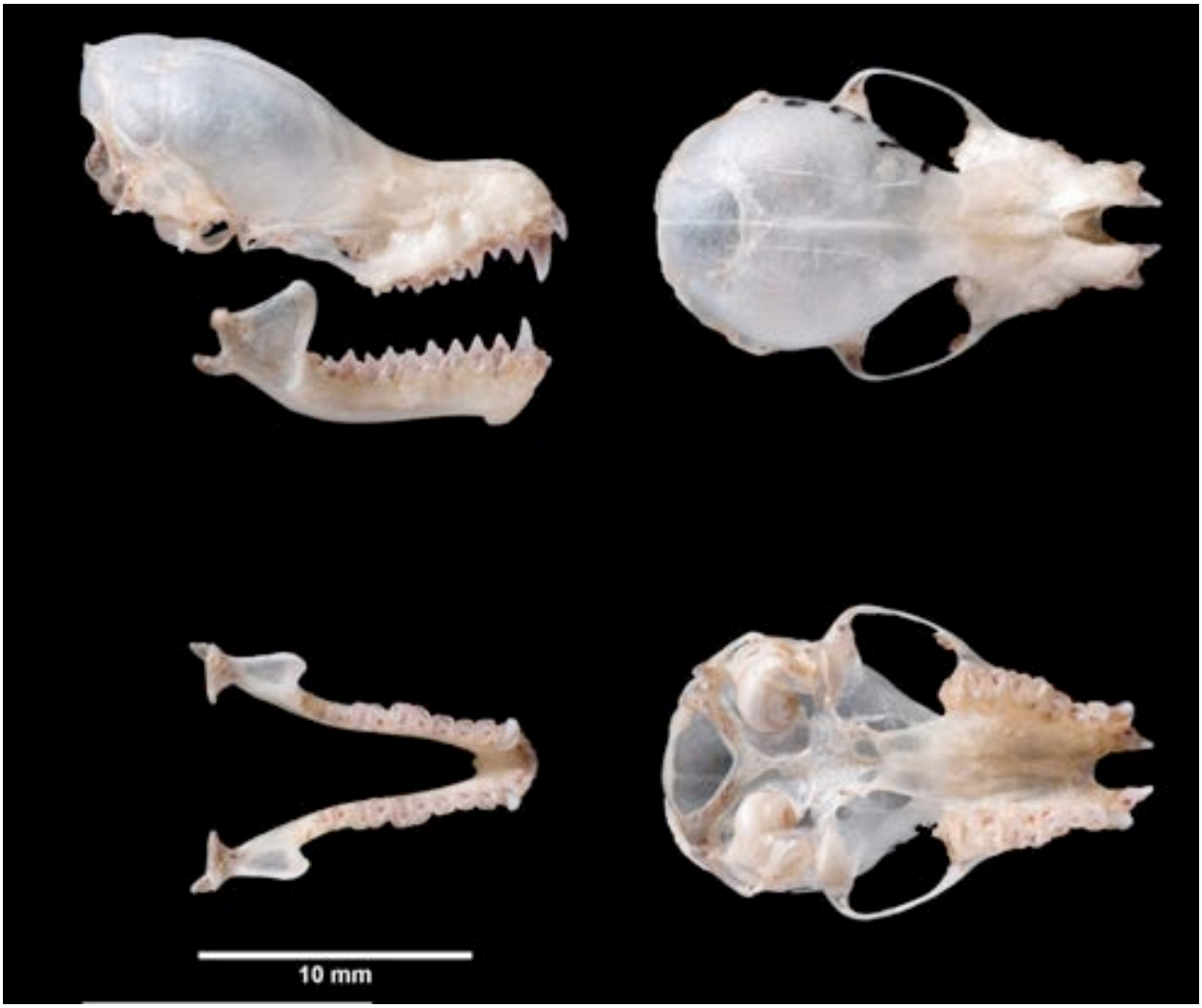

Image 5. Dorsal, ventral & lateral view of cranium and lateral & ventral view of mandible of *Kerivoula kachinensis* from Laitkynsew, Meghalaya (specimen ZSIS-571). © M. Ruedi.

of 3.7–4.1 mm length is present on the joint of the first digit in each wing of our specimens.

Craniodental characters: The skull of the two collected individuals is broad and distinctly flattened (Image 5). Such flattening of skull is not known in any of the other large *Kerivoula* and distinguishes it from the similar-looking *K. lenis* (Bates et al. 2004). The nasal notch in the rostrum is V-shaped. The coronoid process of each mandible is well developed and much exceeds the condyle in height. The upper incisors are unicuspid and about equal in crown area. Each has a cingulum on the postero-internal border. The second incisor is about half the length of the first. The canine is without a longitudinal groove on the outer surface and without a posterior cutting edge, unlike in other Asiatic congeners (Bates et al. 2004). Skull dimensions are presented in Table 2 and are very similar to those reported for female *K. kachinensis* from southeastern Asia (Soisook et al. 2007).

Echolocation calls: Calls were typical of Kerivoulinae (Douangboubpha et al. 2016), very brief (duration 3.3±0.4, range 2.5–3.8 ms) and extremely frequency modulated (Figure 1). The recorded pulses started very high, at around 213 kHz (Fhi 212.7±18.0, range 165.4–225.9 kHz) and ended at around 30kHz (Flo 84.0±2.7, range 80.8–89.3 kHz), thus showing a remarkably broad band width (128.7±16.7, range 84.2–142.5 kHz). The frequency of maximum energy was not sharply defined, at around 110kHz (FmaxE 109.2±1.3, range 107.4–111.7 kHz). Interpulse intervals were short (13.4±2.0, range 10.4–16.1 ms). As the single bat recorded was hand-held, it is likely that these calls characteristics are not typical of free-flying animals, as they would generally emit longer, less frequency modulated calls and at

Table 2. External and craniodental measurements (mean and range in parenthesis) of *Myotis pilosus* based on two released and three voucher specimens (ZSIS-354, 480, 481) and of *Kerivoula kachinensis* (two voucher females ZSIS-454 and 571) from Meghalaya. Measurements for female *K. kachinensis* from southeastern Asia (Soisook et al. 2007) are given for comparison.

Measurements (in mm)	*My. pilosus*	*Ke. kachinensis*	*Ke. kachinensis* (Soisook et al. 2007)
TL	45.2 (42.0–48.0)	(48.0–50.0)	58.3 (55.8–61.0)
E	19.6 (17.5–20.5)	(10.7–14.0)	14.9 (13.2–16.0)
TR	8.0 (7–9)	(6.9–8.1)	-
FA	53.4 (51.1–54.3)	(40.3–41.4)	41.7 (40.1–42.6)
TB	20.8 (20.3–21.3)	(20.9–23.1)	23.1
HF (c.u.)	18.5 (17.2–19.6)	(8.2–8.5)	9.1 (8.6–9.4)
GTL	19.8 (19.7–19.9)	(16.3–16.6)	
GTLi	20.20 (20.2–20.2)	(17.0–17.5)	(17.3–18.4)
CCL	17.90 (17.8–18.0)	(15.4–15.5)	(15.5–16.1)
ZB	12.90 (12.8–13.0)	(10.2–10.6)	(10.7–11.0)
BB	9.65 (9.6–9.7)	(8.1–8.4)	(8.1–8.2)
MAB	10.06 (9.8–10.3)	(8.6–8.7)	(8.4–8.4)
POC	4.83	(3.6–3.6)	(3.6–3.7)
CM^3	7.86 (7.8–7.9)	(6.7–6.8)	(6.7–7.2)
M^3M^3	8.50 (8.5–8.6)	(6.2–6.5)	-
C^1C^1	5.82 (5.7–5.9)	(4.3–4.4)	-
M^1M^3	4.65 (4.5–4.9)	(3.5–3.9)	-
ML	15.24 (15.2–15.3)	(12.0–12.6)	-
MLi	15.55 (15.4–15.8)	(12.2–12.8)	(12.9–13.0)
CM_3	8.53 (8.5–8.5)	(7.2–7.5)	(7.3–7.6)
M_1M_3	5.07 (5.0–5.1)	(4.0–4.2)	-

longer intervals.

Ecological notes: In Laitkynsew, this bat was caught in a harp trap in a tropical evergreen forest patch near the village. Other bats recorded in this forest included *Rhinolophus pearsoni, R. macrotis, Hipposideros pomona, Murina pluvialis* and *M. jaintiana*. In Sakwa, a single individual was caught just outside a cave, in a harp trap with very little bat activity at the time, in a mixed evergreen forest dominated by bamboo.

***Miniopterus magnater* Sanborn, 1931**

Western Bent-winged Bat

New material: Four males and three females, 12.xi.2014, ZSIS-298 to 304, Krem Labit, Shnongrim (25.359^{0}N, 92.512^{0}E; 1,050m), East Jaintia Hills District; two females, 19.ii.2015, ZSIS-351,352, above a river to the east of Umlyngsha (25.209^{0}N, 92.272^{0}E; 675m), East Jaintia Hills District; one male and one female, 21.iii.2018, ZSIS-460, 461, Siju Cave (25.351^{0}N, 90.684^{0}E; 130m), South Garo Hills.

Description and taxonomic notes: This is the largest among the three *Miniopterus* species found in India with a mean forearm length of 50.6mm (range 48.8–52.4 mm) measured in 72 individuals from Meghalaya (Table 3). This exceeds the mean value of 47.0mm (range 44.7–49.6 mm) reported by Bates & Harrison (1997) for "*M. schreibersii*" from the Indian subcontinent, a species now considered as *M. fuliginosus* (Maeda et al. 1982; Appleton et al. 2004). The later values are indeed coherent with those measured in nine *M. fuliginosus* from Himachal Pradesh (Table 3), and are thus also smaller than those of *M. magnater* for most external characters. The third species, *M. pusillus* is much smaller (FA 43 mm or less). The examined specimens of *M. magnater* from Meghalaya have dark brown to blackish dorsal pelage (Image 6). Ears, wings and interfemoral membranes were dark brown. As in its congeners, the second phalanx of the third metacarpal is unusually long with an average length of 39.3mm.

Craniodental characters: Craniodental measurements also support a strong differentiation between *M. magnater* and *M. fuliginosus* in India, with

Image 6. Portraits of (A) *Miniopterus magnater* (released individual) and (B) *M. pusillus* from Umlyngsha, Meghalaya (specimen ZSIS-570). Note the darker facial tone in *M. magnater* and pinkish one in *M. pusillus*. Animals are not to scale. © M. Ruedi.

no overlap of values between those two species (Table 3). Again, the measurements given by Bates & Harrison (1997) for the Indian subcontinent likely correspond to those of *M. fuliginosus* (e.g., mean CCL 14.1mm, range 13.6–14.8 mm; and mean CM^3 6.1mm, range 5.8–6.3 mm), not to *M. magnater* (mean CCL 15.56mm, range 15.4–15.7 mm; mean CM^3 6.85mm, range 6.8–7.1 mm). The dentition of *M. magnater* was strong with prominent canines (Image 7).

Bacular structure: We found no baculum in the male specimens examined, which is the prevalent situation in the genus *Miniopterus* (Topal 1958; Schultz et al. 2016).

Echolocation calls: The structure of the echolocation calls of *M. magnater* recorded free-flying in front of a cave (Figure 1) were typical of miniopterine bats (Wordley et al. 2014; Srinivasulu & Srinivasulu 2017), with a brief (4.9±0.7, range 3.5–5.7 ms) and strongly frequency-modulated sweep terminated by a narrow band tail. The recorded pulses of *M. magnater* started at 118kHz (Fhi 117.6±6.7, range 109.7–129.7 kHz), ended at 39kHz (Flo 39.0±0.7, range 37.9–40.1 kHz), and had a broad band width (78.7±7.0, range 70.1–91.8 kHz). The frequency of maximum energy was marked at 47kHz (FmaxE 46.5±1.5, range 44.5–49.6 kHz) and interpulse intervals were short (69.4±10.1, range 54–94 ms). These characteristics are similar to those reported for *M. fuliginosus* (Wordley et al. 2014; Srinivasulu & Srinivasulu 2017), except for a shorter band width (mean 44.4 vs 78.7 kHz) and a higher frequency at maximum energy (52.0 vs 46.5 kHz), consistent with the smaller size of this species compared to *M. magnater* (Table 3).

***Miniopterus pusillus* Dobson, 1876**
Nicobar Long-fingered Bat

New material: One female, 16.ii.2011, ZSIS-570, near the Umlyngsha Village (25.208^{0}N, 92.271^{0}E; 690m), East Jaintia Hills.

Description and taxonomic notes: This is the smallest amongst the three *Miniopterus* species from the Indian subcontinent (Table 3). An adult female was caught in a mist net placed across a river near the village of Umlyngsha, East Jaintia Hills District. Externally, the animal had slightly lighter fur colour (lighter brown) when compared to the dark brownish individuals of *M. magnater* (Image 6A). The face was also lighter, flesh-coloured; the ears also appeared more delicate, without any obvious fold (Image 6B). The forearm length of the Meghalaya specimen was 43.0mm and had a tibia length of 17.6mm which were much smaller than in the other two congeners from India (Table 3).

Craniodental characters: The skull dimensions of our specimen are considerably smaller than in other *Miniopterus* from India (Table 3), but similar to those given by Bates & Harrison (1997). The dentition is much more delicate too, particularly the smaller canines and molars (Image 8), compared to that of *M. magnater* (Image 7). Unfortunately, no ultrasound recordings could be done with the only caught specimen, but the characteristics for the species recorded in southern India can be found elsewhere (Wordley et al. 2014).

DISCUSSION

The bat fauna of the northeastern Indian state of Meghalaya is astonishingly diverse with well over half of the 127 bat species reported from India (Saikia 2018; Saikia et al. 2018). While some distribution information on the bat species of Meghalaya is available (Ruedi et al. 2012b; Saikia et al. 2018), taxonomic and ecological information is scant (Sinha 1999a). A number of bat

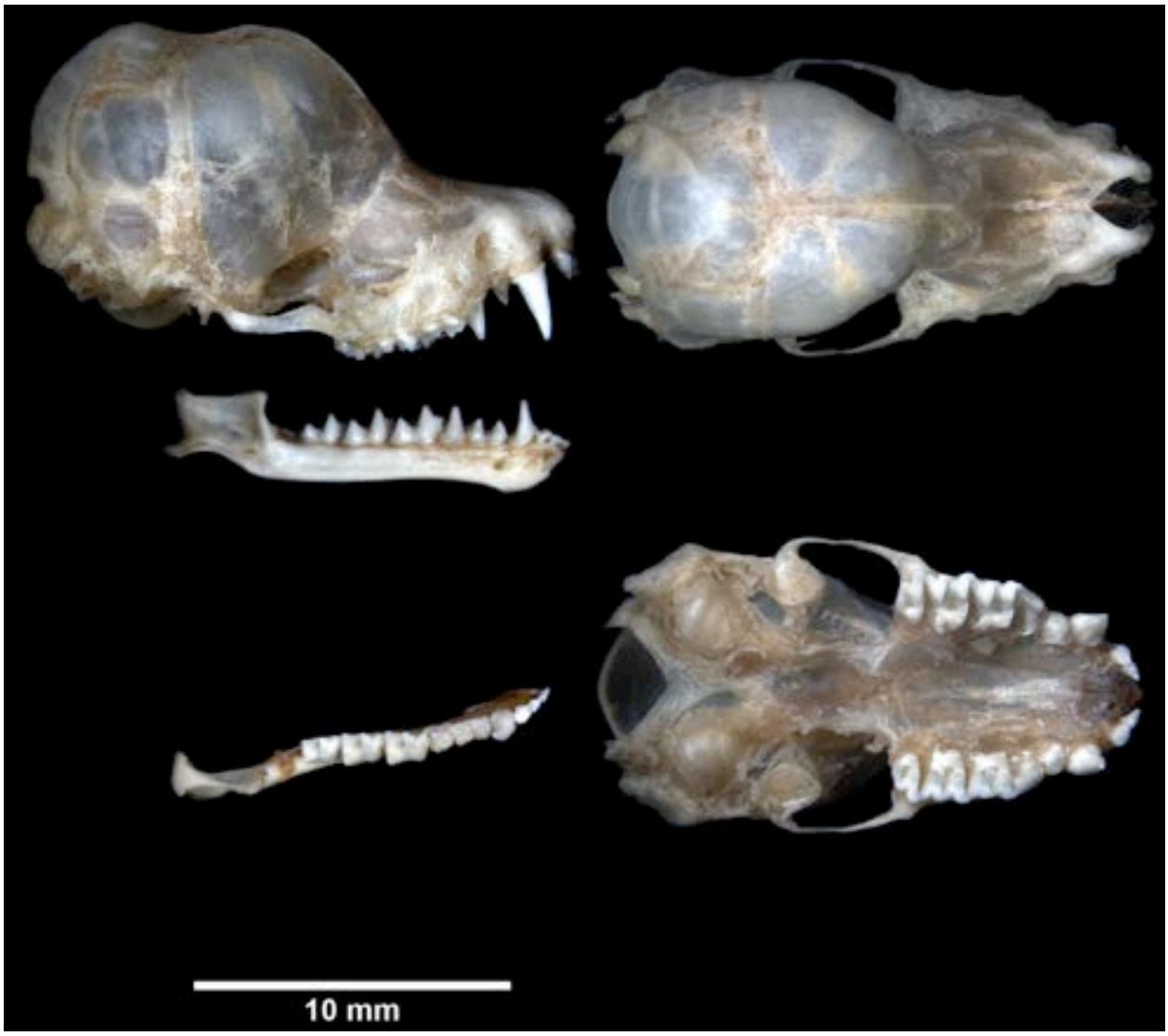

Image 7. Dorsal, ventral & lateral view of cranium and lateral & ventral view of mandible of *Miniopterus magnater* specimen from Siju Cave (specimen ZSIS-461). © U. Saikia.

species like *Eptesicus pachyotis, Myotis horsfieldii*, or *Scotomanes ornatus* are known from Meghalaya only by old records, while a few like *M. niphanae*, *Hypsugo joffrei*, *K. kachinensis, M. magnater, M. pusillus, M. pilosus* or *M. altarium* have only recently been recorded from the state (Ruedi et al. 2012a,b; Saikia et al. 2017, 2018; Thong et al. 2018). Among these newly recorded bats from Meghalaya, *K. kachinensis, M. magnater*, and *M. pilosus* are not known from any other parts of India. Even for species like *M. niphanae* and *M. pusillus* which are known from some other parts of the country, taxonomic and biological information are lacking. Therefore, any information on biology and ecology of these lesser known bat species will contribute to a better understanding of the bat fauna of the country.

Ratanaworabhan's Fruit Bat *M. niphanae* is one of the least common and most poorly known pteropodids found in Meghalaya. The similar-looking *M. ecaudatus* is smaller, with a forearm length of 51.5–56 mm and condylobasal length of 24.0–26.3 mm (Yenbutra & Felton 1983), and has no tail (Francis 1989). It is believed to live in southeastern Asia, however, considering the unusually large range of forearm length (52–63 mm) reported for specimens of *M. niphanae* in northeastern India (Mandal et al. 1993, 1997; Bates & Harrison 1997), Saha (1984), and Bates et al. (2008a) suggest that some of those records may in fact represent *M. ecaudatus*, not *niphanae*. Likewise, the surprisingly large variations of morphological and craniodental measurements given by Das (2003) for Arunachal Pradesh specimens (Table 1)

Image 8. Dorsal, ventral & lateral view of cranium and lateral & ventral view of mandible of *Miniopterus pusillus* specimen from Umlyngsha, Meghalaya (specimen ZSIS-570). © M. Ruedi.

also may represent a mixture of both species. Therefore, besides *M. niphanae* which we document here for Meghalaya, *M. ecaudatus* may also exist in India at least in the easternmost parts of the country.

Since its description from Myanmar (Bates et al. 2004), the Kachin Woolly Bat *K. kachinensis* was reported only from southeastern Asia (Thong et al. 2006; Soisook et al. 2007) until Ruedi et al. (2012b) mentioned its first occurrence in India, but without any taxonomic or metric information. Measurements of the present specimens from Meghalaya are thus the first for the country, and conform well to those of specimens from southeastern Asia (Table 2). Individuals were also caught in dense forest patches as in other parts of its range in southeastern Asia (Bates et al. 2004; Thong et al. 2006; Soisook et al. 2007).

Sinha (1999a,b) reported the presence of *Miniopterus schreibersii fuliginosus* (=*M. fuliginosus*) from Siju Cave in Meghalaya and also provided biometric details of specimens collected from that cave. We, however, recently noted that the mensural data of the Siju *Miniopterus* provided by Sinha, and those from all other large specimens from Meghalaya likely corresponded to that of the larger species *M. magnater* (Ruedi et al. 2012b). We have re-examined and re-measured the specimens from Siju Cave collected by Sinha and confirm that they all represent *M. magnater*. Considering that *M. magnater* is widespread and common at least in the Jaintia and Garo hills (Saikia et al. 2018), and that none of the examined specimens from Meghalaya could be positively assigned to *M. fuliginosus*, it is possible that the latter does not occur in this state.

Rickett's Big-footed Myotis *M. pilosus* is known to be distributed in China, Hong Kong, Vietnam, and Lao PDR (Csorba & Bates 2008). Thabah (2006), however, reported the occurrence of this species (as *M. ricketti*) from Phlang Karuh Cave (Nogtrai) in Meghalaya and till now was known only from this single locality in India.

Table 3. External and craniodental measurements of three *Miniopterus* species found in India. Reported values for *M. magnater* are based on 12 voucher specimens (five males and seven females) and 60 released individuals from Meghalaya. For *M. fuliginiosus*, values are based on six voucher specimens and three released animals from Himachal Pradesh. For *M. pusillus*, only one voucher specimen (female ZSIS-570) was considered.

Measurements (in mm)	*Mi. magnater* Meghalaya	*Mi. fuliginosus* Himachal Pradesh	*Mi. pusillus* Meghalaya
TL	57.0 (54.0–60.0)	58.1 (55.5–60.0)	51.0
E	12.9 (10.5–14.2)	11.4 (9.5–12.9)	11.0
TR	5.7 (4.1–6.8)	5.5 (5.5–5.5)	4.8
FA	50.6 (48.8–52.4)	48.6 (47.5–50.2)	43.0
TB	21.6 (20.4–22.5)	20.4 (20.0–21.0)	17.6
HF (c.u.)	9.5 (9.0–10.4)	10.7 (10–11.2)	7.6
GTL	16.73 (16.5–16.8)	15.69 (15.6–15.8)	13.9
GTLi	17.05 (16.9–17.1)	16.10 (15.9–16.2)	14.0
CCL	15.66 (15.5–15.9)	14.63 (14.5–14.9)	12.7
ZB	9.82 (9.8–10.2)	9.05 (8.9–9.2)	7.9
BB	8.57 (8.5–8.7)	8.19 (8.1–8.4)	7.4
MAB	9.33 (9.2–9.5)	8.96 (8.9–9.0)	8.0
POC	4.29 (4.2–4.4)	4.01 (4.0–4.1)	3.5
CM^3	6.85 (6.8–7.1)	6.23 (6.1–6.5)	5.3
M^3M^3	7.46 (7.0–7.7)	6.86 (6.8–7.0)	5.8
C^1C^1	5.23 (5.2–5.3)	4.85 (4.8–4.9)	4.1
M^1M^3	3.85 (3.9–3.9)	3.58 (3.6–3.6)	3.1
ML	12.81 (12.7–12.9)	11.60 (11.3–11.9)	9.9
MLi	13.19 (12.9–13.3)	11.78 (11.5–12.2)	10.0
CM_3	7.28 (7.2–7.4)	6.75 (6.7–6. 8)	5.6
M_1M_3	4.21 (4.0–4.4)	4.05 (4.0–4.1)	3.6
CoH	2.90 (2.8–3.0)	2.70 (2.7–2.7)	2.4

We could observe or collect specimens of this species from a few other localities like Krem Dam in Mawsynram and Amarsang in West Khasi Hills District of Meghalaya. Additionally, we examined a preserved male specimen collected from a cave near Larket Village (25.374^{0}N, 92.627^{0}E) in East Jaintia Hills District (Khlur Mukhim, in litt.). This species is, thus, more widely distributed in western Meghalaya, albeit in small numbers. The bats in the cave at Nongtrai were observed cohabiting with other species such as *Myotis siligorensis*, *Ia io*, *Hipposideros armiger*, *H. lankadiva*, and *Rhinolophus pearsonii*. It was also found to roost in the cave crevices outside the cave entrance during the colder months of December and January. More recently (2016 and onwards), this important cave has been disturbed due to limestone mining in a nearby location. As a consequence, some of the passages have collapsed and underground spaces have become increasingly unstable over the years, which led a substantial proportion of the roosting bats to abandon this cave. A similar and worrying situation prevails in the Siju Cave, which used to hold large populations of bats, mainly *Eonycteris* and *Miniopterus* (Sinha 1999a), but during two recent visits (March 2017 and March 2018) we did not observe any large colonies of these bats. Regular monitoring and population surveys in these important cave roosts are required to quantify this decline and to take conservation measure to protect them from further degradation.

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COMMUNICATION

Angiosperm diversity in Bhadrak region of Odisha, India

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Abstract: We present the information about angiosperm species in Bhadrak District of Odisha, India. In so doing, we assess the state of floristic knowledge across ecoregions of the district and pinpoint our understanding of the district flora. This study is first of its kind conducted in the district showing current status of the angiosperm diversity. A total of 383 species (262 native species and 121 non-native species) belonging to 282 genera under 93 families are recorded as per APG III classification. These taxa are distributed in 12 superorders and 39 orders; 26.7% of the native species were reported from the superorder Fabids, 20.6% from superorder Malvids, 19.8% from superorder Lamids and 15.6% from superorder Commelinids. One hundred and twenty one non-native species were represented in 12 superorders. Native species of the order Fabales (35), Poales and Lamiales (27) each, Malphigiales (18), Malvales (14), Gentianales (13), Carylophyllales and Solanales (12) each and Myrtales and Sapindales (11) each, account for about 68.7% of the species in the district. Eighty one non-native species belong to these orders. The analysis of the plant species based on growth habits showed highest proportion of herbs followed by trees, shrubs and climbers. Some of the reported species are used for the treatment of various ailments and also for edible purposes. Plant species diversity, distribution and population structure provide baseline information for conservation and sustainable management of available resources.

Keywords: Biofencing, floristic inventory, invasive species, medicinal plants, vegetation.

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Author contribution: TP carried out the floristic study, collected the data and wrote the manuscript. BKP, SDR, RKM and RBM identified the species, interpreted the data and designed the manuscript. All authors have read and approved the final manuscript.

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INTRODUCTION

The structure, composition, and vegetative functions are most significant ecological attributes of a particular ecosystem, which show variations in response to environmental as well as anthropogenic variables (Timilsina et al. 2007; Gairola et al. 2008; Shaheen et al. 2012). Major threats to ecosystems and biodiversity are habitat loss &fragmentation, overexploitation, pollution, invasions of alien species, and global climate change (IUCN 2003) with disruption of community structure. The anthropogenic pressures, heavy grazing, and the natural calamities have led to degradation of natural habitats of many species. Such practices are discouraging the native species and promoting the hardy non-native species having little value for the local ecosystem (Pant & Samant 2012). Floristic inventory and diversity studies help to understand the species composition and diversity status of a region (Phillips et al. 2003), which also offer vital information for conservation (Gordon & Newton 2006). Quantitative inventories, moreover, help identify species that are in different stages of vulnerability (Padalia et al.2004) as well as the various factors that influence the existing vegetation in any region (Parthasarathy 1999). The flowering plants of India comprise about 15,000 species under 2,250 genera and 315 families and represent 6% of the world's known flowering plants (Nayar 1977). At present there are18,666 species of angiosperms found in India (Mao & Dash 2019). According to Irwin &Narasimhan (2011), 49 angiosperm genera are endemic to India. At present 58 genera & 4,303 taxaof angiosperms are endemic to India (Singh et al. 2015).

Odisha, a state of ancient land and temples lying between 17.49N to 22.34N latitude and 81.27E to 87.29E longitude is situated on the eastern coast of the Indian peninsula. Bordered on the north by Jharkhand, on the west by Chhattisgarh, on the south by Andhra Pradesh, on the north-east by West Bengal and on the south-east by Bay of Bengal with a coastline of 482km, the state covers an area of 155,707km^2. This state is a land of rich floral diversity. More than 2,630 species of angiosperms under 194 families (Sahoo et al. 1999) have been recorded in the state. These include trees of commercial significance and plants with medicinal properties. Many botanists have documented the plant diversity of Odisha for nearly two centuries. Roxburgh (1819) was the first to include some plants of southern Odisha. Dunlop (1844) published a list of plants in the garden of the branch Agri-Horticultural Society of Cuttack. Some account of vegetation of Odisha is found in Hooker &Thomson's Flora Indica (1855). Hooker (1897) refers to the stray collections from Odisha. Haines' The Botany of Bihar and Orissa (1925) and its supplement by Mooney (1950) and Gamble's Flora of the Presidency of Madras (1936) are the pioneer works before independence. After independence, many floristic works have been published, thus contributing significantly to the floristic diversity of Odisha. Numerous publications (Jain et al. 1975; Saxena 1976, 1978; Behera et al. 1979; Brahmam & Saxena 1980; Mishra et al. 1983; Choudhury 1984; Choudhury & Pattanaik 1985; Dubey & Panigrahi 1986; Das et al. 1994) either as district floras or checklists of plants of different areas in the state have been brought out. Saxena and Brahmam's The Flora of Orissa published in 1996 is the most comprehensive and authentic work on the floristic diversity of this region. Recently, Reddy et al. (2007) and Sahu et al. (2007) made significant contribution to the flora of Odisha. A perusal of literature, however, reveals that there is a lack of base line information on the floristic composition of Bhadrak District of Odisha. Hence this study was undertaken to explore the angiospermic diversity of the region along with its multifarious uses in rural areas. This study will allow further evaluation of district's current conservation status and contribute to the flora of coastal Odisha.

MATERIALS AND METHODS

Study site

Odisha is the ninth largest state of India by area and the eleventh largest by population. With the Eastern Ghats range of hills almost passing through the heart of the state, high Similipala hills on its north and around 482km of coast line on its east, Odisha has varied ecosystems from marine to semi-arid on the west, which provides 'niches' for diverse animal and plant communities (Patnaik 1996). The vegetation found in this region is tropical moist deciduous forest type (Champion &Seth 1968).

Bhadrak District (21.066^{0}N & 86.5^{0}E) is located in northeastern Odisha. It spreads over 2,505km^2 having 1.507 million inhabitants (2011 Census). Four other districts namely Balasore, Kendrapara, Jajpur and Koenjher surround Bhadrak District while a part is bounded by the Bay of Bengal (Figure 1). The district covers about 1.61% of the total land area of the state and contributes 3.59% of the state's population. About 86.66% of the inhabitants are villagers and the people are engaged in agricultural practices as their primary occupation. Being situated in close proximity to Bay of

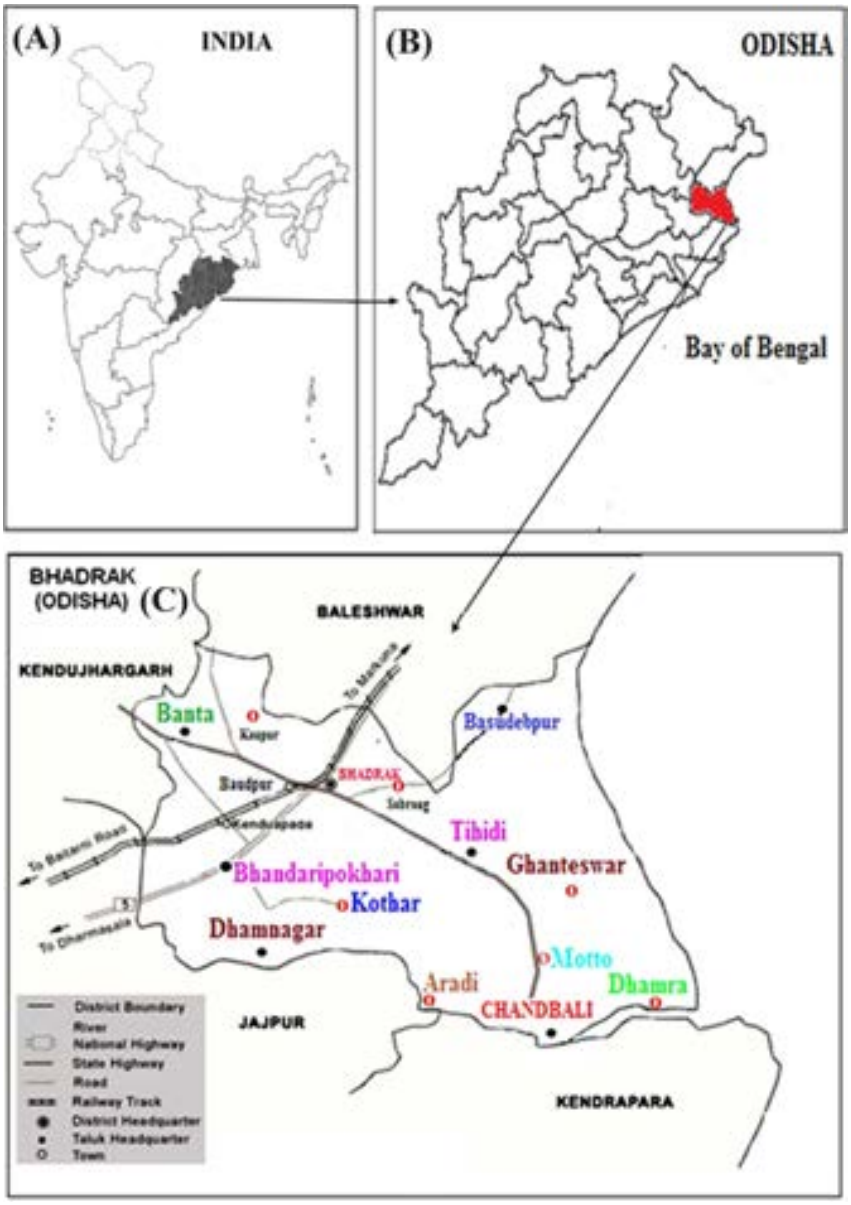

Figure 1. A—Location of Odisha State in the eastern region of India | B—Odisha State indicating Bhadrak District | C—study area showing different blocks of Bhadrak District.

Bengal, the district is characterized by periodic earth tremors, thunder storms in the rains and dust storms in April and May.

Data collection

Extensive field surveys (July 2014 to June 2016) were carried out fortnightly to document and enlist the angiospermic floras in different seasons and diverse habitats, i.e., cultivated fields, waste lands, river banks, roadsides, water bodies, marshes, pathways, parks, private gardens and other relevant localities of the district following established and standard procedures (Jain 1987; Martin 1995). The information was obtained through a combination of tools and techniques of structured questionnaires, complemented by free interviews and informal conversations (Martin 1995; Huntington 2000). The information regarding the plant species has been gathered mostly from local farmers, elderly and knowledgeable persons, who were considered by their communities as having exceptional knowledge about plants.One-hundred-and-fifty-three (128 men and 25 women) persons were interviewed. Among the interviewees, 10% were of ages 21-40 years, 40% were 61 years old or more, and 50% were of ages of 41–60 years. Personal interviews and group discussions carried out in the local language revealed specific information about the plants, which were further compared and authenticated by crosschecking (Cunningham 2001).

During field study, some of the field characters like habit, habitat, flowering period and local names if any were collected and recorded from the informants.The economic uses of these species if any were discussed with the local people. Plant samples were identified or confirmed with available regional floras (Haines 1925; Saxena & Brahmam 1996). Collected literatures by other scholars concerning nativity of species (Negi & Hajra 2007; Reddy 2008; Singh et al. 2010; Khuroo et al. 2012) were consulted.The plant species are enumerated and arranged as per Angiosperm Phylogeny Group III Classification (APG III 2009). The voucher specimens were deposited in the herbarium of the Department of Botany, Chandbali College, Chandbali.

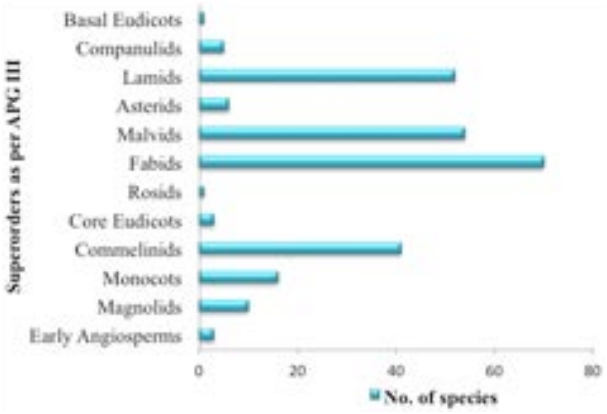

Figure 2. Distribution of native species in superorders as per APG III

RESULTS

The present study documents a total of 383 species (262 native species and 121 non-native species) distributed in 282 genera, representing 93 families as per APG III classification (Table 1; Images 1–9). These taxa are distributed in 12 superorders (Figure 2) and 39 orders; 26.7% of the native species were reported from the superorder Fabids, 20.6% from superorder Malvids, 19.8% from superorder Lamids and 15.6% from superorder Commelinids. One hundred and twenty one non-native species were represented in 12 superorders. Native species of the order Fabales (35), Poales and Lamiales (27) each, Malphigiales (18), Malvales (14), Gentianales (13), Carylophyllales and Solanales (12) each and Myrtales and Sapindales (11) each, account for about 68.7% of the species in the district (Figure 3). Eighty one non-native species belong to these orders. The top 10 families are depicted in Figure 4. Family Fabaceae contributed the largest number of species (35 sp.), followed by Poaceae (21 sp.), Malvaceae (14 sp.), Convolvulaceae (12sp.) and Euphorbiaceae (9sp.). Twenty seven families of the native and 10 families of non-native were represented by one species, contributing 10.3% and 8.3% respectively of the total number families in the inventory. It is demonstrated that native species represented a higher proportion (262 species; 68.4%) than the non-natives (121 species; 31.6%). The genus *Ipomoea* ranked highest with six species followed by *Euphorbia, Clerodendrum, Ficus,* and *Terminalia* each with four species. The analysis of the recorded plant species based on growth habits showed highest proportion of herbs followed by trees, shrubs and climbers (Figure 5).

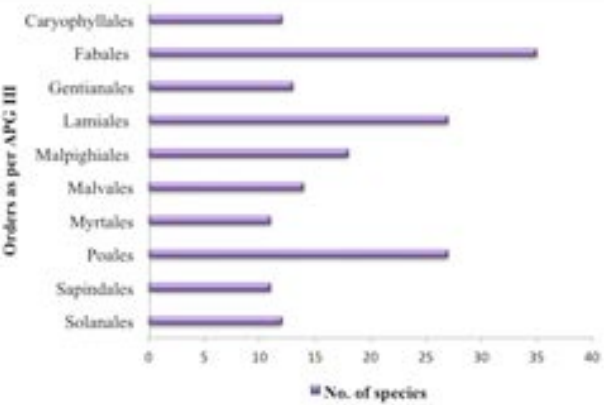

Figure 3. Distribution of native species in orders as per APG III.

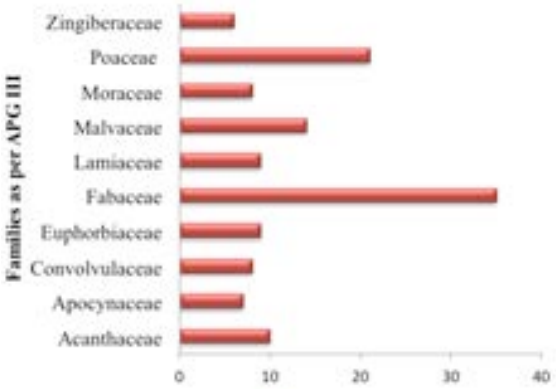

Figure 4. Top ten families with number of species as per APG III.

The economic use of different plant species is represented in Figure 6. Prominent species used for the treatment of various ailments were *Abrus precatorius* L., *Abutilon indicum* (L.) Sweet, *Acacia nilotica* (L.) Delile, *Justicia adhatoda* L.,*Aegle marmelos* (L.) Corrêa, *Andrographis paniculata* (Burm.f.) Wall.ex. Nees,

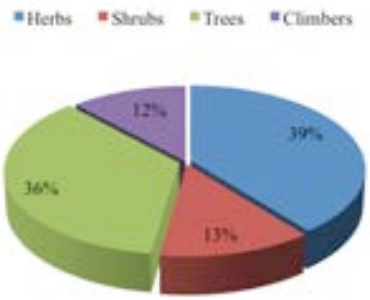

Figure 5. Growth form analysis of native species

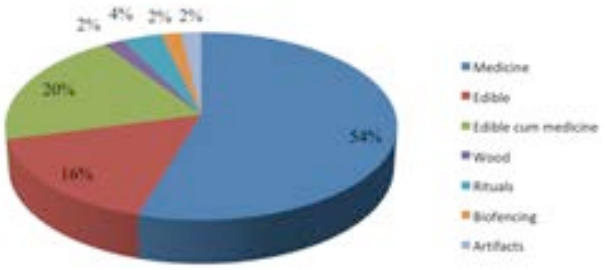

Figure 6. Economically important plants collected at the study site.

Asparagus racemosus Willd.,*Azadirachta indica* A.Juss., *Bacopa monnieri* (L.) Pennell, *Boerhavia diffusa* L., *Butea monosperma* (Lam.) Taub., *Calophyllum inophyllum* L., *Catharanthus roseus* (L.) G.Don., *Centella asiatica* (L.) Urb., *Cissus quadrangularis* L., *Curcuma longa* L., *Cynodon dactylon* (L.)Pers., *Cyperus rotundus* L., *Eclipta prostrata* (L.) L., *Enydra fluctuans* Lour., *Evolvulus alsinoides* (L.) L., *Glinus oppositifolius* (L.) A.DC., *Gymnema sylvestre* (Retz.) R.Br.ex Schult., *Holarrhena pubescens* Wall. ex G. Don., *Ipomoea aquatica* Forssk., *Jatropha curcas* L., *Lawsonia inermis* L., *Macrotyloma uniflorum* (L.) Verdc., *Moringa oleifera* Lam., *Murraya koenigii* (L.) Spreng., *Nyctanthes arbor-tristis* L., *Ocimum sanctum* L., *Oxalis corniculata* L., *Phyllanthus emblica* L., *Pongamia pinnata* (L.) Pierre.,*Punica granatum* L.,*Rauvolfia serpentina* (L.) Benth.ex Kurz, *Ricinus communis* L., *Saraca asoca* (Roxb.) De Wilde, *Sesamum indicum* L., *Solanum surattense* Burm. f.,*Streblus asper* Lour., *Strychnos nux-vomica* L., *Syzygium cumini* (L.) Skeels, *Terminalia arjuna* (Roxb.ex DC.) Wight &Arn., *Terminalia bellirica* (Gaertn.) Roxb., *Tinospora cordifolia* (Willd.) Hook.f. & Thomson, *Tridax procumbens* L., *Vitex negundo* L. and *Zingiber officinale* Roscoe. These plants are used for the treatment of variety of diseases such as diabetes, gastrointestinal disorders, fever, gynaecology, cardiovascular disorders, skin diseases, urinary disorders, rheumatism, jaundice, respiratory disorders and dental caries.Similarly, some of the of the reported plant species are used for edible purposes, for example *Alocasia macrorrhizos* (L.) G.Don, *Alternanthera sessilis* (L.) R. Br., *Amaranthus viridis* L., *Amorphophallus paeoniifolius* (Dennst.) Nicolson, *Anacardium occidentale* L., .*Ananas comosus* (L.) Merr., *Artocarpus heterophyllus* Lam., *Artocarpus lakoocha* Roxb., *Averrhoa carambola* L., *Basella alba*L., *Boerhavia diffusa* L., *Centella asiatica* (L.) Urb., *Colocasia esculenta* (L.) Schott, *Diospyros melanoxylon* Roxb., *Dillenia indica* L., *Enydra fluctuans* Lour., *Feronia limonia* (L.) Swingle, *Glinus oppositifolius* (L.) A. DC., *Ipomoea aquatica* Forssk., *Macrotyloma uniflorum* (L.) Verdc., *Mangifera indica* L., *Mimusops elengi* L., *Oxalis corniculata* L., *Sonneratia apetala* Buch. Ham., *Trapa natans* L. and *Ziziphus mauritiana* Lam. are used as vegetables. A number of edible plants like *Alternanthera sessilis* (L.) R. Br., *Bacopa monnieri* (L.) Pennell, *Boerhavia diffusa* L., *Centella asiatica* (L.) Urb., *Eclipta prostrata* (L.) L., *Enydra fluctuans* Lour., *Hygrophila auriculata* Schum. (Heine), *Ipomoea aquatica* Forssk., *Murraya koenigii* (L.) Spreng. and *Oxalis corniculata* L. are reported to have both therapeutic and dietary functions and hence are used as medicinal food remedy.

Plant species like *Aeschynomene aspera* L., *Borassus flabellifer* L., *Cyperus alopecuroides* Rottb., *Phoenix sylvestris* (L.) Roxb. and *Chrysopogon zizanioides* (L.) Roberty in the present study is used for various household articles. Similarly, the leaves of *Phoenix sylvestris* (L.) Roxb. are used in many religious and socio-cultural functions in the district. The important timber and fuel yielding plant species recorded in our study are *Albizia lebbeck* (L.) Benth., *Alstonia scholaris* (L.) R.Br., *Bambusa vulgaris* L., *Casuarina equisetifolia* L., *Dalbergia sissoo* Roxb., *Litsea glutinosa* (Lour.) C.B. Rob, *Mangifera indica* L., *Polyalthia longifolia* (Sonn.) Thwaites, *Pongamia pinnata* (L) Pierre, *Pterocarpus marsupium* Roxb.,*Samanea saman* (Jacq.) Merr., *Syzygium cumuni*(L.) Skeels and *Tamarindus indica* L.Similarly, a variety of plant species are used for biofencing pupose. Examples include, *Bambusa vulgaris* L., *Bougainvillea spectabilis* Willd., *Calotropis gigantea* R.Br., *Clerodendrum inerme* (L.) Gaertn., *Duranta repens* L., *Euphorbia tirucalli* L., *Gliricidia sepium* (Jacq.) Kunth ex Walp., *Ipomoea carnea* Jacq., *Jatropha curcas* L., *Pandanus fascicularis* Lam. and *Vitex negundo* L. Some of the plants like *Areca catechu* L., *Cynodon dactylon* (L.) Pers., *Desmostachya bipinnata* (L) Stapf, *Mangifera indica* L., *Nelumbo nucifera* Gaertn. and *Piper betel* L. are used for various rituals by the inhabitants of the district.

A good number of plant species are used as tooth stick for general brushing. Examples include *Acacia nilotica* (L.)Willd., *Aegle marmelos* (L.) Corrêa, *Azadirachta*

Table 1. List of angiosperm taxa recorded from Bhadrak District, arranged according to the Angiosperm Phylogeny Group Classification III.

Superorder/ Order	Family & Species	Common name	Habit	Nativity
Early Angiosperms				
Nymphaeales	**Nymphaeaceae**			
	Nymphaea nouchali Burm. f.	Kain	Herb	Native
	Nymphaea pubescens Willd.	Rangakain	Herb	Native
	Euryale ferox Salisb.	Kanta Padma	Herb	Native
MAGNOLIIDS				
Piperales	**Aristolachiaceae**			
	Aristolochia indica L.	Balbolena	Climber	Native
	Piperaceae			
	Piper betel L.	Pana	Climber	Native
	Piper longum L.	Pipal	Climber	Native
	Piper nigrum L.	Golmaricha	Climber	Native
	Peperomia pellucida (L.) Kunth		Herb	Invasive/SAM
Laurales	**Lauraceae**			
	Cassytha filiformis L.	Nirmuli	Climber	Native
	Cinnamomum tamala Nees.	Tejpatra	Tree	Native
	Cinnamomum zeylanicum Blume	Dalchini	Tree	Native
Magnoliales	**Annonaceae**			
	Annona squamosa L.	Neuwa	Tree	Native
	Annona reticulata L.	Atta	Tree	Invasive/TAM
	Artabotrys hexapetalous (L.f.) Bhandari	Chinichampa	Shrub	Native
	Polyalthia longifolia (Sonn.) Thwaites	Debdaru	Tree	Exotic/SR
	Magnoliaceae			
	Magnolia champaca (L.) Baill.ex Pierre	Champa	Tree	Native
MONOCOTS				
Alismatales	**Aponogetonaceae**			
	Aponogeton natans (L.) Engl. &Krause	Jhechu	Herb	Native
	Aponogeton undulatus Roxb.	Kesarkanda	Herb	Native
	Araceae			
	Alocasia macrorrhizos (L.) G.Don	Badasaru	Herb	Native
	Amorphophallus paeoniifolius (Dennst.) Nicolson	Olua	Herb	Native
	Caladium bicolor (Aiton) Vent.		Herb	Native
	Colocasia esculenta (L.) Schott	Saru	Herb	Native
	Pistia stratiotes L.	Borajhanji	Herb	Invasive/TAM
	Hydrocharitaceae			
	Hydrilla verticillata (L. f.) Royle	Chingudiadala	Herb	Native
	Ottelia alismoides (L.) Pers.	Panikundri	Herb	Native
Dioscoreales	**Dioscoreaceae**			
	Dioscorea alata L.	Khamba-alu	Climber	Invasive/ SEA
	Dioscorea pentaphylla L.	Tungialu	Climber	Native
Pandanales	**Pandanaceae**			
	Pandanus fascicularis Lam.	Kia	Shrub	Native
	Pandanus foetidus Roxb.	Lunikia	Shrub	Native
Liliales	**Colchicaceae**			
	Gloriosa superba L.	Ognisikha	Climber	Native
Asparagales	**Amaryillidacea**e			
	Crinum asiaticum L.	Arsa	Herb	Native
	Scadoxus multiflorus (Matyn) Raf.		Herb	Exotic/TAF
	Asparagaceae			
	Agave americana L.	Baramasi	Shrub	Exotic/AM

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Asparagus racemosus Willd.	Satabari	Climber	Native
	Sansevieria roxburghiana Schult. & Schult.f.	Muruga	Herb	Native
	Xanthorrhoeaceae			
	Aloe vera (L.) Burm. f.	Gheekunwari	Herb	Native
COMMELINIDS				
Arecales	**Arecaceae**			
	Areca catechu L.	Gua	Tree	Native
	Borassus flabellifer L.	Tala	Tree	Invasive/TAF
	Calamus rotang L.	Betta	Shrub	Native
	Cocos nucifera L.	Nadia	Tree	Native
	Phoenix sylvestris (L.) Roxb.	Khajuri	Tree	Native
	Phoenix paludosa Roxb.	Hental	Tree	Native
Commelinales	**Commelinaceae**			
	Commelina benghalensis L.	Kansiri	Herb	Native
	Tradescantia spathacea Sw.		Herb	Native
	Pontederiaceae			
	Eichhornia crassipes (Mart.) Solms	Bilatidala	Herb	Invasive/TAM
Poales	**Bromeliaceae**			
	Ananas comosus (L.) Merr.	Sapuri	Herb	Native
	Poaceae			
	Bambusa arundinacea (Retz.)Willd.	Kantabaunsa	Tree	Native
	Bambusa vulgaris Schrad.	Baunsa	Tree	Native
	Chloris barbata Sw.		Herb	Invasive/TAM
	Chrysopogon aciculatus (Retz.) Trin.	Guguchia	Herb	Native
	Coix lacryma-jobi L.	Grgara	Shrub	Exotic/TAS
	Cymbopogon flexuosus (Nees ex Steud.) Wats.	Dhanatwari	Herb	Native
	Cynodon dactylon (L.) Pers.	Duba	Herb	Invasive/TAF
	Dactyloctenium aegyptium (L.) Willd.		Herb	Native
	Desmostachya bipinnata (L) Stapf	Kusa	Herb	Native
	Digitaria sanguinalis (L) Scop.		Herb	Native
	Digitaria ciliaris (Retz.) Koeler		Herb	Native
	Echinochloa colona (L.) Link	Swanghas	Herb	Invasive/SAM
	Echinochloa crusgalli (L.) P. Beauv.	Dhera	Herb	Invasive/SAM
	Eragrostis gangetica (Roxb.) Steud.		Herb	Native
	Eleusine indica (L.) Gaertn.	Anamandia	Herb	Native
	Heteropogon contortus (L.) P. Beauv.		Herb	Native
	Oplismensus burmanii (Retz.) P. Beauv.		Herb	Native
	Oryza rufipogon Griff.	Balunga	Herb	Native
	Paspalidium flavidum (Retz.) A. Camus		Herb	Native
	Pennisetum alopecuros Steud.		Herb	Native
	Phragmites karka (Retz.) Trin.ex Steud.		Shrub	Native
	Saccharum officinarum L.	Akhu	Herb	Native
	Saccharum spontaneum L.	Kashatundi	Herb	Invasive/TWA
	Setaria pumila (Poir.) Roem. & Schult.		Herb	Native
	Setaria verticillata (L.) P. Beauv.		Herb	Native
	Sporobolus indicus (L.) R. Br.		Herb	Native
	Chrysopogon zizanioides (L.) Roberty [=*Vetiveria zizanioides* (L.) Nash]	Bena	Herb	Native
	Cyperaceae			
	Cyperus alopecuroides (Rottb. Descr.)	Hensuati	Herb	Native
	Cyperus difformis L.	Swonli	Herb	Exotic/TAM

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Cyperus rotundus L.	Mthaghas	Herb	Invasive/ER
	Eleocharis palustris (L.) Roem.& Schult.		Herb	Native
	Kyllinga nemoralis (J.R. & G. Forst.) Dandy ex Hutch. & Dalziel		Herb	Native
	Scirpus articulatus L.		Herb	Native
	Scirpus grossus L.	Santara	Herb	Native
	Typhaceae			
	Typha angustifolia L.	Hangla	Herb	Invasive/TAM
Zingiberales	**Musaceae**			
	Musa paradisiaca L.	Kadali	Herb	Native
	Zingiberaceae			
	Hellenia speciosa ***(J.Koenig) S.R.Dutta [= Costus speciosus (J.Koenig) Sm.***	Kokola	Herb	Native
	Curcuma amada Roxb.	Amada	Herb	Native
	Curcuma aromatica Salisb.	Palua	Herb	Native
	Curcuma longa L.	Haldi	Herb	Native
	Elettaria cardamomum (L.) Maton	Gujurati	Herb	Native
	Zingiber officinale Roscoe	Ada	Herb	Native
BASAL EUDICOTS				
Proteales	**Nelumbonaceae**			
	Nelumbo nucifera Gaertn.	Padma	Herb	Native
CORE EUDICOTS				
Dilleniales	**Dilleniaceae**			
	Dillenia indica L.	Awoo	Tree	Native
Ranunculales	**Menispermaceae**			
	Cissampelos pareira L.	Akanbindi	Climber	Exotic/SAM
	Tiliacora racemosa Colebr.	Kalajati noi	Climber	Native
	Tinospora cordifolia (Willd.)Hook.f. & Thomson	Guluchilata	Climber	Native
	Papaveraceae			
	Argemone mexicana L.	Kantakusuma	Herb	Invasive/CAM & SAM
ROSIDS				
Vitales	**Vitaceae**			
	Cissus quadrangularis L.	Hadabhanga	Shrub	Native
FABIDS				
Zygophyllales	**Zygophyllaceae**			
	Tribulus terrestris L.	Gokhara	Herb	Invasive/TAM
Celastrales	**Celastraceae**			
	Celastrus paniculata Willd.	Leibeheda	Shrub	Native
Oxalidales	**Oxalidaceae**			
	Averrhoa carambola L.	Karmanga	Tree	Native
	Oxalis corniculata L.	Ambiliti	Herb	Invasive/ER
Malpighiales	**Euphorbiaceae**			
	*Acalypha hipsida*Burm. f.	Sibajata	Herb	Native
	Acalypha indica L.		Herb	Native
	Euphorbia hirta ***L.*** [=*Chamaesyce hirta* (L.)Millsp.]		Herb	Invasive/TAM
	Croton sparsiflorus Morong	Nandababuli	Herb	Invasive/SAM
	Euphorbia antiquorum L.	Deuliasiju	Shrub	Native
	Euphorbia hirta L.	Harharika	Herb	Invasive/TAM
	Euphorbia heterophyla L.		Herb	Invasive/TAM
	Euphorbia nivulia Buch.-Ham	Bad siju	Tree	Native

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Euphorbia thymifolia L.	Patrasiju	Shrub	Native
	Euphorbia tirucalli L.	Dangulisiju	Shrub	Exotic/KEN
	Euphorbia tithymaloides L.		Shrub	Native
	*Excoecaria agallocha*L.	Guan	Tree	Native
	Jatropha curcas L.	Jara	Shrub	Exotic/TAM
	Jatropha gossypiifolia ***L.***	Baigaba	Shrub	Exotic/TAM
	Ricinus communis L.	Jada	Shrub	Exotic/SAF
	Synadenium grantii Hook f.		Shrub	Invasive/TAM
	Tragia involucrata L.	Bichhuati	Herb	Native
	Trewia nudiflora L.	Panigambhari	Tree	Native
	Linaceae			
	Linum usitissimum L.	Pesu	Herb	Native
	Passifloraceae			
	*Passiflora foetida*L.	Jhumkalata	Climber	Invasive/SAM
	Calophyllaceae			
	Calophyllum inophyllum L.	Polang	Tree	Native
	Phyllanthaceae			
	Breynia vitis-idaea (Burm. f.) C.E.C. Fisch.	Pohalakuli	Shrub	Exotic/WI
	Phyllanthus emblica L.	Anola	Tree	Native
	Phyllanthus fraternus Webster	Bhuianla	Herb	Native
	Rhizophoraceae			
	Bruguiera cylindrica (L.) Blume	Kaliachua	Tree	Native
	Bruguiera parviflora (Roxb.) Wright & Arn. ex Griff.	Dot	Tree	Native
	Kandelia candel (L.) Druce	Rasunia	Tree	Native
	Rhizophora mucronata Poir.	Rai	Tree	Native
	Violaceae			
	Hybanthus enneaspermus (L.) F. Muell.		Herb	Native
Fabales	**Fabaceae**			
	Abrus precatorius L.	Kaincha	Climber	Native
	Acacia nilotica (L.) Delile	Babulla	Tree	Native
	Acacia leucophloea (Roxb.) Willd.		Tree	Native
	Aeschynomene aspera L.	Solo	Herb	Native
	Albizia lebbeck (L.) Benth.	Sirish	Tree	Native
	Alysicarpus monilifer (L.) DC.		Herb	Native
	Bauhinia purpurea L.	Nalikanchana	Tree	Native
	Bauhinia variegata L.	Kanchan	Tree	Native
	Butea monosperma (Lam.) Taub.	Palasa	Tree	Native
	Caesalpinia bonduc (L.) Roxb.	Gilo	Climber	Native
	*Caesalpinia crista*L.	Nantei	Climber	Native
	Caesalpinia pulcherrima (L.) Sw.	Krushnachuda	Tree	Native
	Sennaalata (L.) Roxb. [= *Cassia alata* L.]		Herb	Invasive/TAM
	Sennaauriculata (L.) Roxb. [= *Cassia auriculata* L.]		Tree	Native
	Cassia fistula L.	Sunari	Tree	Native
	Sennaoccidentalis (L.) Link [= *Cassia occidentalis* L.]	Kalachakunda	Herb	Invasive/TAM
	Sennatora (L.) Roxb.[= *Cassia tora* L.]	Chakunda	Herb	Invasive/TAM
	Clitoria ternatea L.	Aparajita	Climber	Native
	Crotalaria juncea L.	Chanapata	Shrub	Native
	Crotalaria spectabilis Roth.	Jhumka	Herb	Native
	Dalbergia sissoo Roxb.	Sisoo	Tree	Native

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Derris scandens (Roxb.) Benth.	Mohagano	Climber	Native
	Erythrina indica Lam.	Paladhua	Tree	Native
	Gliricidia sepium (Jacq.) Kunth ex Walp.		Tree	Native
	Lablab purpureus (L.)Sweet	Shimba	Climber	Native
	Leucaenia leucocephala (Lam.) de Wit	Rajokasundari	Tree	Native
	Macrotyloma uniflorum (L.) Verdc.	Kolatha	Herb	Native
	Mimosa pudica L.	Lajakuli	Herb	Invasive/BR
	Mucuna pruriens (L.) DC.	Baidanka	Climber	Native
	Pithecellobium dulce Roxb.	Simakaina	Tree	Native
	Pongamia pinnata(L.) Pierre	Karanj	Tree	Native
	Prosopsis cineraria (L.) Druce	Sami	Tree	Native
	Prosopis juliflora (Sw.) DC.		Tree	Invasive/MEX
	Pterocarpus marsupium Roxb.	Piasala	Tree	Native
	Samanea saman (Jacq.) Merr.	Chakunda	Tree	Native
	Saraca asoca (Roxb.) De Wilde.	Ashoka	Tree	Native
	Sesbania grandiflora (L.) Poir.	Agasthi	Tree	Native
	Tamarindus indica L.	Tentuli	Tree	Exotic/AF
	Tephrosia purpurea (L.) Pers.	Banakolathi	Herb	Native
	Vigna mungo (L.) Hepper	Biri	Herb	Native
	Vigna radiata (L.) R. Wilczek	Mugo	Herb	Native
	Vigna unguiculata (L.) Walp.	Judanga	Climber	Native
Rosales	**Cannabaceae**			
	Cannabis sativa L.	Ganjei	Herb	Invasive/CAS
	Moraceae			
	Artocarpus heterophyllus Lam.	Panasa	Tree	Native
	Artocarpus lakoocha Roxb.	Jeutha	Tree	Native
	Ficus benghalensis L.	Baro	Tree	Native
	Ficus elastica Roxb.	Rubber	Tree	Native
	Ficus hipsida L.f.	Dimri	Tree	Native
	Ficus religiosa L.	Aswastha	Tree	Native
	Morus alba L.	Tutkoli	Tree	Native
	Streblus asper Lour.	Sahada	Tree	Native
	Rhamnaceae			
	Ziziphus mauritiana Lam.	Barakoli	Tree	Invasive/AUS
	Ziziphus oenoplia (L.) Mill.	Kankoli	Shrub	Native
Cucurbitales	**Cucurbitaceae**			
	Benincasa hipsida (Thunb.) Cogn.	Panikakharu	Climber	Invasive/SEA
	Citrullus lanatus (Thunb.) Matsum. & Nakai	Tarbhuj	Climber	Invasive/WAF
	Coccinia indica Wight & Arn.	Kunduri	Climber	Native
	*Lagenaria siceraria (*Molina) Standley	Laoo	Climber	Invasive/AF
	Luffa acutangula (L.) Roxb.	Pitataradi	Climber	Native
	Trichosanthes cucumerina L.	Banapotala	Climber	Native
	Trichosanthes dioica Roxb.	Potala	Climber	Native
	Trichosanthes tricuspidata Lour.	Mahakal	Climber	Native
Fagales	**Casuarinaceae**			
	Casuarina equisetifolia L.	Jhaun	Tree	Native
MALVIDS				
Myrtales	**Combretaceae**			
	Terminalia arjuna (Roxb.ex DC.) Wight & Arn.	Arjuna	Tree	Native
	Terminalia bellirica (Gaertn.) Roxb.	Bahada	Tree	Native
	Terminalia catappa L.	Kathabadam	Tree	Native

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Terminalia chebula Retz.	Harida	Tree	Native
	Lythraceae			
	Lawsonia inermis L.	Menjuati	Shrub	Native
	Punica granatum L.	Dalimba	Shrub	Native
	Sonneratia apetala Buch.-Ham.	Kerua	Tree	Native
	Sonneratia caseolaris (L.) Engl.	Orua	Tree	Native
	Trapa natans L.	Pani Singada	Herb	Invasive/ER
	Myrtaceae			
	Eucalyptus tereticornis Sm.		Tree	Exotic/AUS
	Psidium guajava L.	Pijuli	Tree	Exotic/TAM
	Syzygium cumini (L.) Skeels	Jamukoli	Tree	Native
	Syzygium jambos (L.) Alston	Gulabjamun	Tree	Exotic/SEA
	Syzygium samarangense (Blume) Merr. & Perry	Jamrul	Tree	Native
	Onagraceae			
	Ludwigia adscendens (L.) H. Hara	Jagal	Herb	Invasive/TAM
	Ludwigia octovalvis (Jacq.) Raven		Herb	Invasive/TAF
	Ludwigia perennis L.	Latkera	Herb	Invasive/TAF
	Ludwigia prostrata Roxb		Herb	Native
Brassicales	**Caricaceae**			
	Carica papaya L.	Amrutabhanda	Tree	Exotic/TAM
	Moringaceae			
	Moringa oleifera Lam.	Sajana	Tree	Native
	Brassicaceae			
	Brassica compestris Hook. f. & Thomson	Sorish	Herb	Exotic/MR
	Brassica juncea (L.) Czern.& Coss.	Raisorisha	Herb	Exotic/CAS
	Cleomaceae			
	Cleome gynandra L.	Arakasago	Herb	Invasive/TAM
	Cleome monophylla L.	Rangasorish	Herb	Invasive/TAF
	Cleome rutidosperma DC.		Herb	Invasive/TAM
	Cleome viscosa L.	Anasorisho	Herb	Invasive/TAM
	Capparaceae			
	Capparis zeylanica L.	Asadua	Climber	Native
	*Crataeva nurvala*Buch.- Ham.	Barun	Tree	Native
	Salvadoraceae			
	Salvadora persica L. var. wightiana Verdc.	Miriga	Shrub	Native
Sapindales	**Anacardiaceae**			
	Anacardium occidentale L.	Saitamba	Tree	Invasive/CAM
	Mangifera indica L.	Amba	Tree	Native
	Spondias mangifera Willd.	Salma	Tree	Native
	Meliaceae			
	Azardiracta indica A. Juss.	Nimba	Tree	Native
	Rutaceae			
	Aegle marmelos (L.) Corrêa	Bela	Tree	Native
	Citrus aurantifolia (Christm.) Swingle	Kagjilembu	Tree	Native
	Citrus grandis (L.) Osbeck	Batapi	Tree	Invasive/SEA
	Citrus medica L.	Lembu	Tree	Native
	Citrus reticulata Blanco	Kamala	Tree	Native
	Feronia limonia (L.) Swingle	Kaitho	Tree	Native
	Murraya koenigii (L.) Spreng.	Bhursunga	Tree	Native
	Sapindaceae			
	Cardiospermum halicacabum L.	Kanphuta	Climber	Native

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Sapindus emarginatus Vahl	Reetha	Tree	Native
Malvales	**Malvaceae**			
	Abutilon indicum (L.) Sweet	Pedipedika	Herb	Native
	Bombax ceiba L.	Simli	Tree	Native
	Corchorus aestuans L.	Bananalita	Herb	Invasive/TAM
	Corchorus capsularis L.	Nalita	Herb	Native
	Corchorus olitorius L.		Herb	Native
	Corchorus trilocularis L.		Herb	Invasive/TAF
	Gossypium herbaceum (L.) Mast.	Kapa	Herb	Invasive/SAF
	Grewia asiatica L.	Pharsakoli	Tree	Native
	Hibiscus esculentus L.	Bhendi	Shrub	Invasive/AF
	Hibiscus rosa-sinensis L.	Mandar	Shrub	Exotic/CH
	Hibiscus sabdariffa L.	Khata Kaunria	Shrub	Native
	Hibiscus tiliaceus L.	Bania	Tree	Native
	Hibiscus vitifolius L.		Shrub	Native
	Malachra capitata (L.) L.		Shrub	Invasive/TAM
	Malvaviscus arboreus Cav.	Lankamandar	Shrub	Exotic/TAM
	Melochia corchorifolia L.	Telpuri	Shrub	Exotic/TAM
	Pavonia zeylanica (L.) Cav.		Herb	Native
	Sida acuta Burm.f.	Sunakhadika	Shrub	Invasive/TAM
	Sida cordata (Burm. f.) Borss. Waalk.	Bisiripi	Herb	Native
	Sida cordifolia L.	Bisiripi	Herb	Native
	Sida rhombifolia L.	Sahabeda	Shrub	Exotic/TAM
	Sida spinosa L.	Bajramuli	Herb	Native
	Sterculia foetida L.	Janglibadam	Tree	Native
	Thespesia populneoides (Roxb.) Kostel	Habali	Tree	Native
Saxifragales	**Crassulaceae**			
	Bryophyllum pinnatum (Lam.) Oken	Amarpoi	Herb	Native
Santalales	**Santalaceae**			
	Santalum album L.	Chandan	Tree	Native
Caryophyllales	**Aizoaceae**			
	Sesuvium portulacastrum (L.) L.	Godabani	Herb	Native
	Trianthema portulacastrum L.	Purinisaga	Herb	Native
	Polygonaceae			
	Antigonon leptopus Hook. & Arn.		Climber	Invasive/TAM
	Polygonum barbatum L.	Nara	Herb	Native
	Polygonum glabrum Willd	Bihongi	Herb	Native
	Polygonum plebeium R.Br.	Muthisaga	Herb	Native
	Molluginaceae			
	Glinus oppositifolius (L.) A.DC.	Pitasaga	Herb	Native
	Amaranthaceae			
	Achyranthes aspera L.	Apamaranga	Herb	Native
	Alternanthera sessilis (L.)R.Br.ex DC.	Madranga	Herb	Invasive/TAM
	Amaranthus spinosus L.	Kantaneutia	Herb	Invasive/TAM
	Amaranthus gangeticus L.	Nalikosala		Invasive/CAM
	Amaranthus viridis L.	Leutia	Herb	Invasive/CAM
	Chenopodium album L.	Bathuasaga	Herb	Invasive/ER
	Gomphrena serrata L.		Herb	Invasive/TAM
	Suaeda maritima (L.) Dumort.	Giriasaga	Herb	Native
	Suaeda monoica Forssk.ex Gmel.		Herb	Native
	Portulacaceae			
	Portulaca oleracea L.	Badabalbaula	Herb	Invasive/SAM

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Portulaca quadrifida L.	Balbaula	Herb	Invasive/TAM
	Nyctaginaceae			
	Boerhavia diffusa L.	Puruni	Herb	Invasive/TAM
	Mirabilis jalaba L.	Chandrakanta	Herb	Invasive/PE
	Bougainvillea spectabilis Willd.	Kagajaphula	Shrub	Exotic/BR
	Basellaceae			
	Basella alba L.	Poi	Climber	Native
	Cactaceae			
	Opuntia stricta (Haw.) Haw. var. *dillenii* (Ker Gawl.) L. D. Benson	Nagapheni	Shrub	Invasive/TAM
	Pilosocereus arrabidae (Lem.) Byles & G.D. Rowley	Deulisiju	Shrub	Native
	Plumbaginaceae			
	Plumbago zeylanica L.	Chintamani	Herb	Invasive/TAF
	Tamaricaceae			
	Tamarix troupii Hole	Jaula	Tree	Native
ASTERIDS				
Cornales	**Cornaceae**			
	Alangium salviifolium (L. f.) Wangerin	Ankula	Tree	Native
	Ebenaceae			
	Diospyros melanoxylon Roxb.	Kendu	Tree	Native
Ericales	**Lecythidaceae**			
	Barringtonia acutangula (L.) Gaertn.	Hinjal	Tree	Native
	Couroupita guianensis Aubl.	Nageswar	Tree	Native
	Sapotaceae			
	Madhuca indica J.F. Gmel.	Mahula	Tree	Native
	Manilkara achras (Mill.) Fosberg	Sapota	Tree	Invasive/CAM
	Mimusops elengi L.	Baula	Tree	Native
LAMIDS				
Gentianales	**Apocyanaceae**			
	Adenium obesum (Forssk.) Roem. &Schult.		Shrub	Native
	Alstonia scholaris (L.) R. Br.	Chhatin	Tree	Native
	Calotropis gigantea R. Br.	Dhala-arakha	Shrub	Invasive/TAF
	Calotropis procera (Aiton)W.T. Aiton	Arakha	Shrub	Invasive/TAF
	Cathranthus roseus (L.) G. Don	Sadabihari	Herb	Invasive/TAM
	Ervatamia divaricata (L.) Burkill	Tagar	Shrub	Native
	Gymnema sylvestre (Retz.) R.Br.exSchult.	Gurmari	Climber	Native
	Holarrhenapubescens Wall. ex G. Don[= *Holarrhena antidysenterica* Wall. ex A. DC.]	Indrajalo	Shrub	Native
	Nerium oleander L.	Karabiro	Shrub	Exotic/CH
	Pergularia daemia (Forssk.) Chiov.	Uturudi	Climber	Native
	Plumeria rubra L.	Kathachampa	Tree	Exotic/MEX
	Rauvolfia serpentina (L.) Benth.ex Kurz	Patalgoruda	Shrub	Native
	Rauvolfia tetraphylla L.		Shrub	Exotic/WI
	Thevetia peruviana (Pers.) K. Schum.	Kaniyara	Tree	Exotic/AM
	Loganiaceae			
	Strychnos nux-vomica L.	Kochila	Tree	Native
	Rubiaceae			
	Anthocephalus cadamba Roxb.	Kadamba	Tree	Native
	Ixora coccinea L.		Shrub	Native
	Morinda pubescens Sm.	Acchu	Tree	Native
	Oldenlandia corymbosa L.	Charpodia	Herb	Native
	Paederia foetida L.	Prasaruni	Shrub	Native

Superorder/ Order	Family & Species	Common name	Habit	Nativity
Lamiales	**Acanthaceae**			
	Andrographis paniculata (Burm.f.)Wall. ex Nees	Bhuinnimba	Herb	Native
	Acanthus ilicifolius L.	Harkanch	Herb	Native
	Avicennia alba Blume	Bani	Tree	Native
	A. marina (Forssk.) Vierh.	Dhalabani	Tree	Native
	A. officinalis L.	Kalabani	Tree	Native
	Barleria prionitis L.	Daskeraanta	Shrub	Native
	Justiciaadhatoda L. [= *Adhatoda vasica* Nees]	Basanga	Shrub	Native
	Hygrophila auriculata Heine	Koelekha	Herb	Native
	Justicia gendarussa Burm.f.	Kalabasanga	Herb	Native
	Ruellia prostrata Poir.		Herb	Native
	Lamiaceae			
	Clerodendrum inerme (L.) Gaertn.	Chinyanrhi	Herb	Native
	Clerodendrum indicum (L.) Kuntze	Nagri	Shrub	Native
	Clerodendrum philippinum Schauer.	Dilbari	Shrub	Native
	Clerodendrum phlomoides L. f.	Donkari	Shrub	Native
	Leucas aspera (Willd.) Link	Gaiso	Herb	Native
	Mentha spicata L.	Podina	Herb	Invasive/ER
	Ocimum basilicum L.	Durlava	Herb	Native
	Ocimum sanctum L.	Tulasi	Shrub	Native
	Tectona grandis L.	Saguan	Tree	Native
	Vitex negundo L.	Begunia	Tree	Native
	Scrophulariaceae			
	Bacopa monnieri (L.) Pennell	Brahmi	Herb	Native
	Limnophila aquatica (Roxb.) Alston	Keralata	Herb	Native
	Lindernia crustacea (L.)F.v.Muell.		Herb	Native
	Martyniaceae			
	Martynia annua L.	Baghanakhi	Shrub	Exotic/TAM
	Plantaginaceae			
	Scoparia dulcis L.	Chirarita	Herb	Invasive/TAM
	Bignoniaceae			
	Kigelia africana (Lam.) Benth.		Tree	Invasive/RH
	Oroxylum indicum (L.) Kurz	Phanaphania	Tree	Native
	Pedaliaceae			
	Pedalium murex L.	Gokara	Herb	Invasive/TAM
	Sesamum indicum L.	Khasa	Herb	Native
	Oleaceae			
	Nyctanthes arbor-tristis L.	Gangaseoli	Tree	Native
	Verbenaceae			
	Duranta repens	Bilatikanta	Shrub	Exotic/AM
	Gmelina arborea Roxb.	Gambhari	Tree	Native
	Lantana camara L.	Gandhagauria	Shrub	Invasive/TAM
	Lippia javanica (Burn.f.)Spreng	Naguari	Herb	Native
Solanales	**Convolvulaceae**			
	Argyreia nervosa (Burm. f.) Bojer	Mundanoi	Climber	Native
	Cuscuta reflexa Roxb.	Nirmuli	Climber	Invasive/MR
	Evolvulus alsinoides (L.) L.	Bichhamalia	Herb	Native
	Evolvulus nummularius (L.) L.		Herb	Invasive/TAM
	Ipomoea alba L.	Kunjalata	Climber	Native
	Ipomoea aquatica Forssk.	Kalamasaga	Climber	Native

Superorder/ Order	Family & Species	Common name	Habit	Nativity
	Ipomoea batatus L.	Kandamula	Climber	Native
	Ipomoea carnea Jacq.	Amari	Shrub	Invasive/TAM
	Ipomoea marginata (Desr.)Verdc.		Climber	Native
	Ipomoea mauritiana Jacq.	Bhuinkakharu	Herb	Native
	Ipomoea sepiaria Koenig ex Roxb.	Mushkani	Herb	Native
	Solanaceae			
	Datura metel L.	Kaladudura	Herb	Invasive/TAM
	Datura stramonium L.	Dudura	Herb	Invasive/TAM
	Solanum melongena L.	Baigan	Herb	Native
	Solanum nigrum L.	Tutguna	Herb	Invasive/TAM
	Solanum virginianum L. [= *Solanum surattense* Burm. f.]	Beji-begun	Herb	Native
	Solanum trilobatum L.	Nabhiankuri	Shrub	Native
	Solanum viarum Dunal	Bhegibaigan	Herb	Invasive/TAM
Boraginales	**Boraginaceae**			
	Heliotropium indicum L.	Hatisundha	Herb	Native
CAMPANULIDS				
Asterales	**Asteraceae**			
	Bidens pilosa L.		Herb	Exotic/TAM
	Acanthospermum hispidum DC.	Gokhura	Herb	Invasive/BR
	Ageratum conyzoides L.	Poksunga	Herb	Invasive/TAM
	Echinops echinatus Roxb.	Batresh	Herb	Invasive/AFG
	Eclipta prostrata (L.) L.	Bhrungaraj	Herb	Invasive/TAM
	Enydra fluctuans DC.	Hidmichi	Herb	Native
	Gnaphalium polycaulon Pers.		Herb	Invasive/TAM
	Helianthus annus L.	Suryamukhi	Herb	Exotic/NAM
	Mikania micrantha Kunth		Climber	Invasive/TAM
	Parthenium hysterophorus L.	Gajarghas	Herb	Invasive/NAM
	Spilanthes paniculata Wall ex DC.		Herb	Native
	Synedrella nodiflora (L.) Gaertn.		Herb	Invasive/WI
	Tagetes erecta L.	Gendu	Herb	Exotic/MEX
	Tridax procumbens L.	Bisalyakarani	Herb	Invasive/CAM
	Xanthium indicum J. Koenig ex Roxb.		Shrub	Invasive/TAM
	Vernonia cinerea (L.) Less.	Poksunga	Herb	Native
	Vicoa indica (L.) DC.	Banasebati	Herb	Native
Apiales	**Apiaceae**			
	Centella asiatica (L.) Urb.	Thalkudi	Herb	Native
	Coriandrum sativum L.	Dhania	Herb	Exotic/MR

Abbreviations: AF—Africa | AFG—Afghanistan | AM—America | AUS—Australia | BR—Brazil | CAM—Central America | CAS—Central Asia | CH—China | ER—Europe | KEN—Kenya | MEX—Mexico | MR—Mediterranean region | NAM—North America | PE—Peru | RH—Rhodesia | SAF—South Africa | SAM—South America | SEA—South East Asia | SR—Sri Lanka | TAF—Tropical Africa | TAM—Tropical America | TAS—Tropical Asia | TWA—Tropical West Asia | WI—West Indies.

indica A. Juss., *Bambusa vulgaris* L., *Butea monosperma* (Lamk.) Taub., *Calotropis procera* (Aiton) W.T. Aiton, *Cinnamomum tamala* Nees, *Jatropha curcas* L., *Lantana camara* L., *Mimusops elengi* L., *Pandanus fascicularis* Lam., *Phoenix sylvestris* (L.) Roxb., *Pongamia pinnata* (L) Pierre, *Psidium guajava* L., *Streblus asper* Lour., *Syzygium cumuni* (L.) Skeels and *Vitex negundo* L. Besides, bark, leaf and rhizome as such or being processed are used as tooth powder. Also raw leaf, bark, root flower bud and pericarp are chewed to remove the bad breath and infection. In few cases the latex, juice or oil extracted from seeds are either directly applied on the effected tooth and gums or gurgled for relief. Moreover, these plant species are exclusively for toothache due to caries, gum diseases and pyorrhea. Oils extracted from seeds of some plants like *Brassica juncea* (L.) Czern., *Helianthus annuus* L. and *Sesamum indicum* L. are either gurgled or applied as lotion on inflammatory gums. And the seeds of *Solanum virginianum* L. are burnt and smoked like cigarette for relief from toothache. Moreover, the leaves of *Aegle marmelos* (L.) Corrêa and *Ocimun sanctum* L. are chewed to prevent bad breath from mouth.Invasive species such as *Ageratum conyzoides* L., *Eichhornia crassipes* (Mart.) Solms, *Lantana camara* L., *Mikania micrantha* Kunth and *Parthenium hysterophorus* L. are causing great concern in many parts of the district.

DISCUSSION

Plants in all ecosystems play a dominant role in determining the life histories of millions of animal species, serve as the foundation of most food webs, and perform a crucial role in human welfare and economic development. The result on the angiosperm diversity of Bhadrak District shows a total of 383 species (262 native species and 121 non-native species) distributed in varied habitats. The general trends of plant species collected in this study are concordant with previous studies in India. For example, a total of 277 plant species belonging to 72 families have been reported in Karnal District, Haryana (Kumar & Singh 2013). A total of 110 species belonging to 82 genera and 40 families are recorded in Khammam District, Telangana State (Rao et al. 2015). A total of total of 252 species belonging to 197 genera distributed in 64 families are recorded in an estuarian ecosystem, Tamil Nadu (Karthigeyan et al. 2013). A total of 138 angiosperm taxa under 120 genera and 50 families are recorded in Dhanbad District, Jharkhand (Rahul & Jain 2014). Samanta & Panda (2016) recorded a total of 80 families, 226 genera, and 270 species at Digha, West Bengal. No published information recorded on the diversity of angiosperm plant species of Bhadrak District, Odisha. The richest families are: Fabaceae (35 sp.), Poaceae (21 sp.), Malvaceae (14 sp.), Convolvulaceae (12sp.), Acanthaceae (10sp.) and Euphorbiaceae (9 sp.). The predominance of family Fabaceae is supported by studies from Víctor et al. (2009), Irwin & Narasimhan (2011), Ramasamy et al. (2012), Anaclara et al. (2013), Ferreira et al. (2013), Jayanthi & Jalal (2015), and Parthian et al. (2016). The growth forms found are trees, shrubs, climbers, and herbs, with the herbaceous component representing the largest number of species. The dominance of herbaceous communities is reported in other parts of world (Víctor et al. 2009; Anaclara et al. 2013; Ferreira et al. 2013), and also in India (Irwin and Narasimhan 2011; Ramasamy et al. 2012; Jayanthi & Jalal 2015; Parthipan et al. 2016). In the present investigation, about 54% of the documented plant species have medicinal utility for a variety of ailments. For instance, the most cited plant species to cure skin disorders in the current investigation are, *Azadirachta indica* A. Juss., followed by *Senna obtusfolia* (L.) H.S. Irwin & Barneby, *Annona squamosa* L., *Pongamia pinnata* (L.) Pierre, *Lantana camara* L., *Tridax procumbens* L., *Argemone mexicana* L., *Calophyllum inophyllum* L., *Andrographis paniculata* Nees, *Amaranthus spinosus* L., *Bauhinia variegata* L., *Butea monosperma* (Lam.) Taub. Similar plant use is recorded earlier in different parts of India (Sharma et al. 2003; Saikia et al. 2006; Jeeva et al. 2007; Kingston et al. 2009; Madhu & Yarra 2011), indicating the importance of traditional medicine in the treatment of skin disorders. Furthermore, various workers have investigated the herbal remedy of the reported plant species used for treatment of different ailment in India (Jeeva et al. 2007; Kar & Borthakur 2008; Binu 2009; Das et al. 2015) and Odisha (Girach et al. 1998; Misra et al. 2012; Pani et al. 2014; Satapathy 2015).

Traditional foods are those which indigenous peoples have access to locally, without having to purchase them and within traditional knowledge and the natural environment from farming or wild harvesting (Kuhnlein et al. 2009). Wild food plants occupy an important place in the rural dietary habits and their consumption particularly during periods of food scarcity and famine is practiced in various regions of the world. Some studies have shown that these plants often provide better nutrition and may be responsible for good health (Grivetti & Ogle 2000; Johns & Eyzaguirre 2006). In Bhadrak District, about 16% plant species are used as subsidiary food and vegetable by indigenous people. Some of the edible plants like *Amorphophallus paeoniifolius*

Image 1. a—*Abrus precatorius* L. | b—*Abutilon indicum* (L.) Sweet | c—*Acacia nilotica* (L.) Delile | d—*Acalypha hipsida* Burm.f. | e—*Acanthus ilicifolius* L. | f—*Achyranthes aspera* L. |g—*Adhatoda vasica* Nees | h—*Aegle marmelos* (L.) Corr. | i—*Ageratum conyzoides* L. | j—*Aloe vera* (L.) Burm.f. | k—*Alstonia scholaris* (L.) R. Br. | L—*Amaranthus spinosus* L. © Taranisen Panda.

(Dennst.) Nicolson, *Ipomoea aquatica* Forssk. and *Trapa natans* L. are domesticated by local people in their individual land/pond but are also available in the wild. Some plant species reported in the present study such as *Colocasia esculenta* (L.) Schott, *Enydra fluctuans* Lour., *Ipomoea aquatica* Forssk.,*Trapa natans* L. and *Nymphaea pubescens* Willd. are reported from other places (Daniel 2007; Panda & Misra 2011; Swapna et al. 2011; Misra et al. 2012). Some of the reported wild edible plants such as *Colocasia esculenta* (L.) Schott, *Ipomoea aquatica* Forssk.and *Trapa natans* L. are found to be sold in the local markets particularly by poor and economically marginalised families, thereby generating a supplementary income. Some of the plant species in the present study are reported from other places (Daniel 2007; Panda & Misra 2011; Swapna et al. 2011; Misra et al. 2012). A number of edible plants like *Alternanthera sessilis* (L.) R. Br., *Bacopa monnieri* (L.) Pennell, *Boerhavia diffusa* L., *Centella asiatica* (L.) Urb., *Eclipta prostrata* (L.) L., *Enydra fluctuans* Lour., *Hygrophila auriculata* Schum. (Heine), *Ipomoea aquatica* Forssk., *Murraya koenigii* (L.) Spreng.and *Oxalis corniculata* L. are reported to have both therapeutic and dietary functions and hence are used as medicinal food remedy. This overlap between food and medicines is well known in traditional societies (Panda & Misra 2011; Swapna et al. 2011; Misra et al. 2012).

A good number of artifact items are prepared from *Aeschynomene aspera* L.and *Chrysopogon zizanioides* L. Roberty by the artisans of the district. Similar observations have also been made in earlier studies (Mohanty et al. 2012; Tripathy et al. 2014). Trees are the main source of fuel wood in the study area. The local people cut trees and use them as a fuel wood. Mostly women are engaged in searching for twigs and some branches from the surrounding forests. Most of the people walk long distances in search for fuel wood. And some of them use their own trees for their fuel wood purpose. According to the study results people use many tree species for fuel wood. Some species are more preferred than others. The most preferred species of trees for their fuel wood value are *Albizia lebbeck* (L.) Benth., *Alstonia scholaris* (L.) R.Br., *Bambusa vulgaris* L., *Casuarina equisetifolia* L., *Litsea glutinosa* (Lour.) C.B. Rob., *Polyalthia longifolia* (Sonn.) Thwaites, *Pongamia pinnata* (L) Pierre, *Samanea saman* (Jacq.) Merr. and *Tamarindus indica* L. The most common parts of a tree species used for fuel wood in Bhadrak District are the branches and twigs. The local people use the wood from different species for constructing house, to prepare some household utensils, farm equipment and construct fences. The study results reveal that the people are dependent on wood tree species for all the above mentioned activities.The use of trees as a source of construction wood is an old activity in Bhadrak District. The stem of *Borassus flabellifer* L. provides strong timber material useful for construction (Kovoor 1983; Depommier 2003). The leaves are used in a variety of artifact construction. For example, for making mats, umbrellas, toys, huts and other household utility products (Kovoor 1983). The pulp is mixed with flour and used to make several edible preparations (Davis & Johnson 1987).The most valuable tree species used for construction purpose by the people are *Acacia* sp., *Dalbergia sissoo* Roxb., *Gmelina arborea* Roxb., and *Pterocarpus marsupium* Roxb. *Acacia nilotica* (L.) Willd. and *Albizia lebbeck*(L.) Benth. is used for agricultural equipments.*Phoenix sylvestris* (L.) Roxb. plant provides a multitude of useful products such as handicrafts and mats, screens, thatching and fencing materials, baskets, crates, fuel wood, brooms and is the main subsistence resource for the poorest people (Rana & Islam 2010).

Live fences are frequent in Bhadrak District separating crop fields, pastures, households, and farm boundaries and forming intricate networks of plant cover across rural landscapes.The local people use the different plant species for biofencing. The most important species used for biofencing purpose are *Acacia nilotica* (L.) Willd., *Albizzia lebbeck* (L.) Benth., *Bambusa arundinacea* (Retz.)Willd., *Bambusa vulgaris* L., *Duranta repens* L., *Euphorbia tirucalli* L., *Jatropha curcas* L., *Lantana camara* L., *Pandanus fascicularis* Lam., *Pilosocereus arrabidae* (Lem.) Byles & G.D.Rowley and *Vitex negundo* L. The respondents mentioned that *Areca catechu* L.,*Cynodon dactylon* (L.) Pers., *Desmostachya bipinnata* (L) Stapf, *Mangifera indica* L., *Nelumbo nucifera* Gaertn. and *Piper betel* L. are the mostly utilized for ritual purpose.

The present report on the use of plants for dental care draws support from earlier studies (Singh & Narain 2007; Saxena & Roy 2007; Wabale & Kharde 2008; Khan et al. 2009; Jain & Chauhan 2009) in different parts of India. Moreover, when the modern mouthwash solutions do nothing more than camouflaging the unpleasant breath for a limited period (Dhilon 1994), the plant species reported in this study are claimed to remove the foul smell from the mouth along with their other medicinal actions. The higher population explosion and limited resources in India demand that some alternative means of organizing oral health and care be examined and implemented (Anonymous 1994). In this context, phytotherapy resources for oral health care appear relevant as it requires no special resources,

Image 2. a—*Andrographis paniculata* (Burm.f.) Wall.ex. Nees | b—*Ananas comosus* (L.) Merr. | c—*Annona squamosa* L. | d—*Antigonum leptopus* Hook & Arn. | e—*Argemone mexicana* L. | f—*Asparagus racemosus* Willd. | g—*Averrhoa carambola* L. | h—*Azadirachta indica* A. Juss. | i—*Barleria prionitis* L. | j—*Boerhavia diffusa* L. | k—*Bombax ceiba* L. | l—*Butea monosperma* (Lam.) Taub. © Taranisen Panda.

sophistication or expertise in production, preparation and usage.

The history of invasive alien plants in Bhadrak District revealed that many species were introduced for economic purposes like timber, ornamental, and green coverage plantation of barren land and some were migrated to this region by transport of food grains from other regions. Climatic conditions of the region became suitable for them and they showed rapid proliferation to spread all over the district. Most of the weeds were reported in the locality for a very long period of time. A questionnaire survey among the informants revealed that there were hardly any management programmes to control invasive alien plants such as *Eichhornia crassipes* (Mart.) Solms,*Lantana camara* L., *Mikania micrantha* Kunth, *Ageratum conyzoides* L. and *Parthenium hysterophorus* L. *Ageratum conyzoides* L. is expanding at an alarming rate, especially in agricultural fields, road sides and even gardens. The weed is harmful to native species and has become a problem in agro-ecosystems (Negi & Hajra 2007). Freshwater species like *Eichhornia crassipes* (Mart.) Solms is of most nuisance as it causes hindrance by choking all possible water bodies and reducing their utility. Similarly *Lantana camara* L. as one of the most ubiquitous invasive land species, is spreading fast all over the district due to its better competitive ability and allelopathic effect (Sundaram & Hiremath 2012). The perennial *Mikania micrantha* Kunth which is a fast growing species, is covering the habitats of the district and suppressing the growth of agricultural crops as well as natural vegetation through competition and allelopathic effects (Sankaran & Srinivasan 2001; Huang et al. 2009). *Parthenium hysterophorus* L. a dominant weed of the study area, especially wastelands, roadsides, railway tracks and foot paths. This noxious weed is an aggressive colonizer spreading rapidly suppressing native herbaceous flora. The spread of these obnoxious invasive weeds should be controlled and they should be removed from the habitat. The results of preference ranking for four selected threats against the availability of plant species in the study area shows that agricultural expansion is the first ranking threat (most detrimental), followed by urbanization, fuel wood collection and overgrazing. In addition to the above mentioned threats the respondents mentioned that limited government support for species conservation and the gradual waning of the existing traditional systems and coping mechanisms due to external intervention are among the main reasons behind the neglecting of local knowledge and tree management and conservation systems.

CONCLUSION

The present inventory of angiosperm plant resources provides a comprehensive and updated checklist of the floristic diversity of the district which can be utilized in the context of species conservation. Currently different habitats of the district are prone to various anthropogenic activities, such as encroachment and conversion of forest areas into agricultural lands and construction of dams and roads, fragmentation and over exploitation of biological resources, pose threat to the existing biodiversity of the district. Fragmentation process shows effect on species, especially on unique, rare and endemic, threatening their survival and resulting in the extinction of species. The present study in the Bhadrak District is preliminary, and subsequent re-census and monitoring will provide additional data on species composition and diversity changes due to various disturbance regimes, which will be useful in resource management and conservation efforts.

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Image 3. a—*Caesalpinia bonduc* (L.) Roxb. | b—*Calamus rotang* L. | c—*Calophyllum inophyllum* L. | d—*Calotropis gigantea* R. Br. | e—*Senna occidentalis* (L.) Link | f—*Senna tora* (L.) Roxb. | g—*Casuarina equisetifolia* L. | h—*Cathranthus roseus* (L.) G. Don | i—*Centella asiatica* (L.) Urb. | j—*Cissampelos pareira* L. | k—*Cissus quadrangularis* L. | l—*Cleome viscosa* L. © Taranisen Panda.

Image 4. a—*Clerodendrum inerme* (L.) Gaertn. | b—*Commelina benghalensis* L. | c—*Couroupita guianensis* Aubl. | d—*Crataeva nurvala* Buch.-Ham. | e—*Crinum asiaticum* L. | f—*Croton sparsiflorus* Morong | g—*Datura metel* L. | h—*Diospyros melanoxylon* Roxb. | i—E*clipta prostrata* (L.)L. | j—*Erythrina indica* Lam. | k—*Euphorbia tirucalli* L. | l—*Evolvulus alsinoides* (L.) L. © Taranisen Panda.

Image 5. a—*Feronia limonia* (L.) Swingle | b—*Ficus hipsida* L. f. | c—*Glinus oppositifolius* (L.) A.DC. | d—*Gloriosa superba* L. | e—*Grewia asiatica* L. | f—*Gymnema sylvestre* (Retz.) R.Br.ex Schult. | g—*Heliotropium indicum* L. | h—*Hybanthus enneaspermus* (L.) F. Muell. | i—*Hydrilla verticillata* (L. f.) Royle | j—*Hygrophila auriculata* Heine | k—*Ipomoea aquatic* Forssk. | l—*Ipomoea batatus* L. © Taranisen Panda.

Image 6. a—*Jatropha gossypiifolia* L. | b—*Kandelia candel* (L.) Druce | c—*Lantana camara* L. | d—*Lawsonia inermis* L. | e—*Leucas aspera* (Willd.) Link | f—*Madhuca indica* J. F.Gmel. | g—*Martynia annua* L. | h—*Mimosa pudica* L. | i—*Mimusops elengi* L. | j—*Morinda pubescens* Sm. | K—*Moringa oleifera* Lam. | l—*Mucuna pruriens* (L.) DC. © Taranisen Panda.

Image 7. a—*Murraya koenigii* (L.) Spreng | b—*Nelumbo nucifera* Gaertn. | c—*Nerium oleander* L. | d—*Opuntia stricta* (Haw.) Haw. var. *dillenii* (Ker Gawl.) L. D. Benson | e—*Oryza rufipogon* Griff. | f—*Oxalis corniculata* L. | g—*Pedalium murex* L. | h—*Pergularia daemia* (Forssk.) Chiov. | i—*Pilosocereus arrabidae* (Lem.) Byles & G.D.Rowley | j—*Plumeria rubra* L. | k—*Pongamia pinnata* (L.) Pierre | l—*Portulaca oleracea* L.

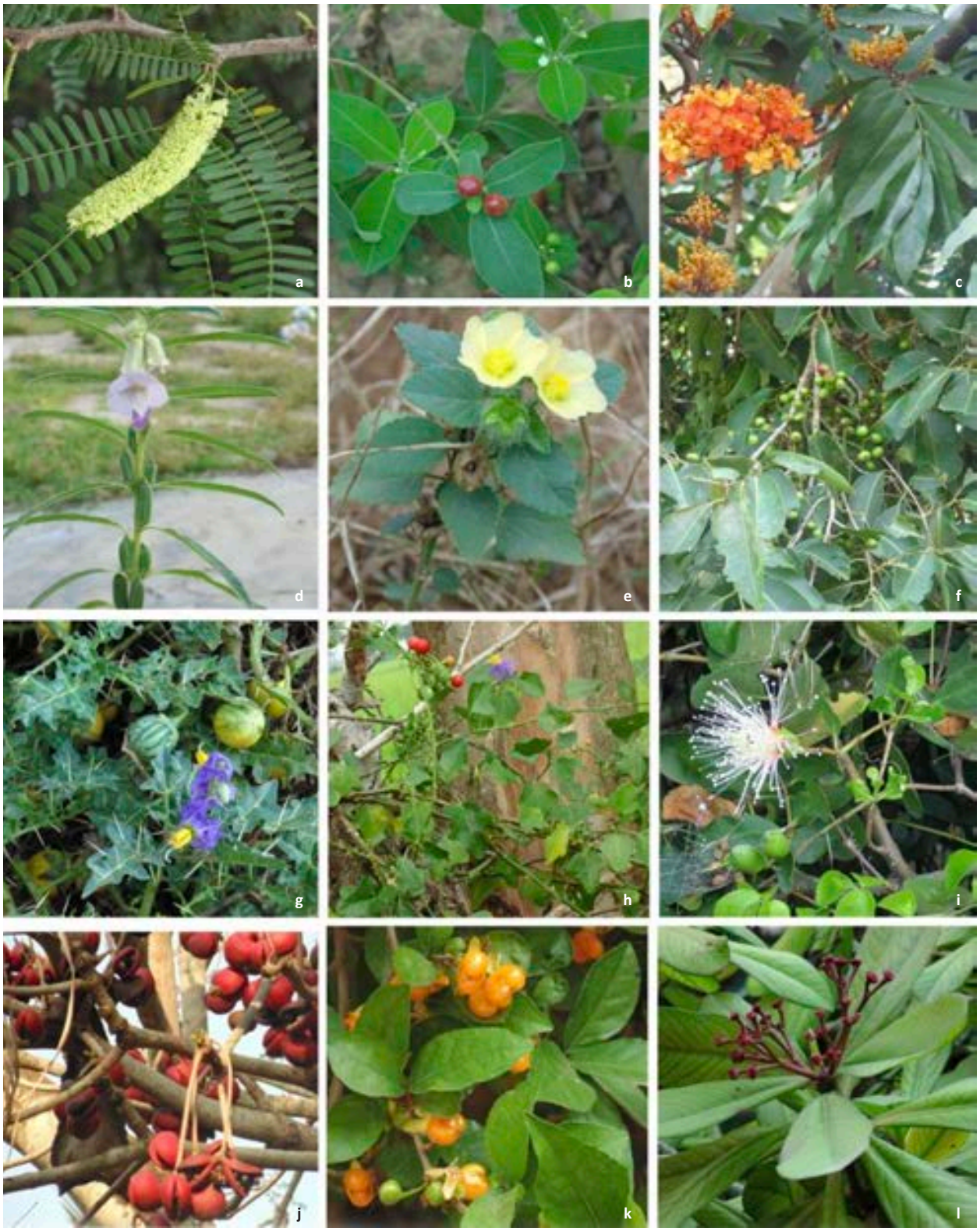

Image 8. a—*Prosopis juliflora* (Sw.) DC. | b—*Rauvolfia tetraphylla* L. | c—*Saraca asoca* (Roxb.) de Wilde. | d—*Sesamum indicum* L. | e—*Sida cordifolia* L. | f—*Syzygium cumini* (L.) Skeels | g—*Solanum virginianum* L. | h—*Solanum trilobatum* L. | i—*Sonneratia caseolaris* (L.) Engl. | j—*Sterculia foetida* L. | k—*Streblus asper* Lour. | l—*Synadenium grantii* Hook f. © Taranisen Panda.

Image 9. a—*Tamarindus indica* L. | b—*Tephrosia purpurea* (L.) Pers. | c—*Terminalia arjuna* (Roxb.ex DC.) Wight &Arn. | d—*Terminalia catappa* L. | e—*Thespesia populneoides* (Roxb.) Kostel | f—*Tinospora cordifolia* (Willd.)Hook.f. & Thomson | g—*Trapa natans* L. | h—*Tribulus terrestris* L. | i—*Tridax procumbens* L. | j—*Typha angustifolia* L. | k—*Vitex negundo* L. | l—*Zizyphus oenoplia* (L.) Mill. © Taranisen Panda.

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SHORT COMMUNICATION

Sighting of *Petaurista petaurista* (Pallas, 1766) (Mammalia: Rodentia: Sciuridae) on limestone hills in Merapoh, Malaysia

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Abstract: Flying squirrels are poorly studied nocturnal mammals as their elusive and nocturnal behaviour makes it hard to observe them in the wild. Here, we describe sightings of *Petaurista petaurista* on a limestone hill and its foot at Merapoh, Pahang, Malaysia. This is the first report as the species is usually known to inhabit forest habitat. We observed the first squirrel resting on a steep limestone wall at night. During subsequent nights, three individuals were observed feeding on *Ficus hispida* and *Terminalia catappa* fruits on the foot of the hill in nearby trees. These sightings suggest that *P. petaurista* may use limestone hill habitat.

Keywords: Ecology, flying squirrels, limestone, nocturnal.

Flying squirrels (hereafter referred to as gliding squirrels) are a group of understudied rodents in the family Sciuridae (Thorington et al. 2012) that belong to 15 different genera in two subtribes—(i) subtribe Glaucomyina: *Eoglaucomys*, *Glaucomys*, *Hylopetes*, *Iomys*, *Petaurillus*, *Petinomys*; (ii) subtribe Peromyina: *Aeretes*, *Aeromys*, *Belomys*, *Biswamoyopterus*, *Eupetaurus*, *Petaurista*, *Pteromys*, *Ptermyscus*, *Trogopterus* (Thorington & Hoffmann 2005). They are primarily nocturnal mammals with varying body sizes from small (80–225 mm head to anus length) to large

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(520–338 mm; Francis 2008). They are popularly known as "flying squirrels" (Prater 2005) because they have a "flying membrane" or patagium that spreads between their extremities to glide between their extremities that enables them to glide over long distances (ca. 90m) between tress.

The Red Giant Gliding Squirrel *Petaurista petaurista* has a wide range from Afghanistan to Borneo (Thorington et al. 2012). There are known subspecies within this geographical range, including those described in southeastern Asia (Corbet & Hill 1992; Silva & Downing 1995; Thorington & Hoffmann 2005; Sanamxay et al. 2015). *Petaurista petaurista* is known to occur in wet tropical lowlands, mountainous temperate forests, coniferous forests, evergreen broadleaf forests, hardwood forests, plantations, and orchards (Molur et al. 2005; Thorington et al. 2012; Smith & Xie 2013). They are predominantly herbivores, feeding on leaves, flowers, and fruits (Muul & Lim 1978; Kuo & Lee 2003). During the day, these squirrels usually stay in their nest in tree cavities (Muul & Lim 1978; Lee et al. 1993) or in epiphytes such as the bird's nest fern; *Asplenium nidus* (P. Miard pers. obs.). *Petaurista petaurista* is listed as Least Concern in the IUCN Red List due to their broad geographic range (Duckworth 2016). This paper reports the first sighting of the little studied *P. petaurista* from limestone hills in Merapoh, Pahang, Malaysia.

Materials and Methods

Study site

The survey area consists of mixed fruit orchards that fringe forested areas within the Merapoh District of Pahang, peninsular Malaysia (4.696^{0}N, 102.000^{0}E). These orchards are planted primarily with durian *Durio* spp., Rambutan *Nephelium lappaceum*, Cocoa *Theobroma cacao*, and other native trees such as figs *Ficus variegata* that also grow in the area naturally. The small township of Merapoh is surrounded by forested areas, including the virgin primary lowland rainforest of Taman Negara Pahang national park at Sungai Relau and several other production forest reserves (i.e., Sungai Yu Forest Reserve, Tanum Forest Reserve, and Persit Forest Reserve), which are situated nearby.

The unique landscape of this area comprises more than 85 characteristic limestone hills and numerous caves, which have been estimated to be between 230 million and 350 million years old (UNESCO 2014; Joeharry et al. 2018). The primary forest covers an area of ca. 4,343km^2 and is estimated to be 130 million years old, making it one of the oldest rainforests in the world (UNESCO 2007). The fauna and flora of the area is diverse with charismatic megafauna such as the Malayan Tiger *Panthera tigris jacksoni* (Kawanishi & Sunquist 2004), Leopard *Panthera pardu*s (Asrulsani et al. 2017), Asian Elephant *Elephas maximus* (Kawanishi et al. 2003), Malayan Tapir *Tapirus indicus* (Kawanishi et al. 2003), Malayan Sun Bear *Helarctos malayanus* (Kawanishi & Sunquist 2008), Barking Deer *Muntiacus muntjac* (Kawanishi et al. 2003), Sambar Deer *Rusa unicolor* (Kawanishi et al. 2003), and Serow *Capricornis sumatrensis* (I. Mukri pers. obs.). Over 250 species of birds, including 69 threatened species, have been recorded within Taman Negara Pahang and Merapoh (BirdLife International 2019).

The biodiversity of limestone hills is often understudied due to the difficulty to access the caves and forests on the top (Clements et al. 2006). The area around Merapoh Town is mostly used for farming, orchards and rubber plantations (Milow et al. 2010). The Merapoh Caves have been intensively surveyed for fossils (Baad 2017). One of the caves called Gua Seribu Cerita contains ancient drawings on the walls suggesting its use by prehistoric peoples (Baad 2017).

Survey method

The survey was conducted for three nights (8–10 December 2018) from 21.00 to 01.00 h along an existing 2km long forest trail and also in an orchard nearby. The trail and the orchard were surveyed on foot by a team of 2–5 people, and animals were sighted using a head torch with a red filter (Clulite HL13). Nocturnal mammals have a bright reflective eye layer, the tapetum lucidum, allowing observers to detect them by eye shine. Sighted mammals were photographed whenever possible for species identification, and data on location, tree species, tree height, and estimated height of sighted mammals in the tree were recorded.

Results

We observed one Red Giant Gliding Squirrel *P. petaurista* directly on a steep limestone hill wall approximately 70m above ground on 8 December 2018 at 22.56h. The individual was resting while occasionally moving its head (Image 1).

During subsequent visits, we recorded two more squirrels (at 00.40h) on 9 December 2018, and one (at 01.12h) on 10 December 2018. The two individuals were feeding on a *Ficus hispida*, known as Hairy Fig (or locally Ara Bumbong, Senia; Aziz et al. 2014) at a height of ca. 20m, while one individual was feeding on *Terminalia catappa*, known as Tropical Almond (family Combretaceae; Nwosu et al. 2008).

Image 1. *Petaurista petaurista* spotted on a limestone hill near Merapoh, Malaysia on the 8 December 2018 at 22.56h.

Image 2. Drone image of the forest below the limestone hill where *Petaurista petaurista* was sighted.

The aerial image (Image 2) shows that these trees are growing just by the foothills making it accessible for wildlife to connect from the forest habitat to the limestones.

Discussion

The taxonomy of *Petaurista* spp. is still under debate (Sanamxay et al. 2015). The subspecies observed in Merapoh, however, might be *P. petaurista melanotus* according to its location (Corbet & Hill 1992). Generally, gliding squirrels use different types of nests such as tree cavities or leaf nests, while subterranean nests are the least common (Holloway & Malcolm 2007; Diggins et al. 2015). *Petaurista petaurista* is known to nest in tree holes that are usually 10–35 m high (Krishna et al. 2019) but also in epiphytes such as bird's nest ferns (*Asplenium nidus*; P. Miard pers. obs. 2017).

Although *P. petaurista* is an extremely agile glider (Krishna et al. 2016), it can also easily climb steep slopes (Scholey 1986). Muul & Lim (1978) sighted *Petaurista* sp. gliding from a limestone hill to trees 300m in distance and 125m down (Thorington & Heaney 1981). Hence, the sightings reported here could indicate that *P. petaurista* may be using these hills more frequently.

The use of limestone hills has also been observed in the Woolly Gliding Squirrel *Eupetaurus cinereus*. Their habitat is described as mountainous conifer forest associated with steep slopes and caves (Zahler 2010).

Use of mineral licks by gliding squirrels has rarely been observed but has been reported from China where up to 20 individuals per night at one mineral lick spot (Xian & Harding 2013). Our sightings may indicate that

P. petaurista may also use limestone hill habitat as a possible source of minerals by licking its surface and/ or as a shelter in its cavities, and further research on the ecology and behaviour of this elusive species is needed to draw a more comprehensive picture on limestone use behaviour.

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Molecular detection of *Murshidia linstowi* in a free-ranging dead elephant calf

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Abstract: Gastrointestinal helminths are ubiquitous in both domestic and wild animals. Infections are often sub-clinical except in circumstances of destabilization of host-parasite equilibrium by innate or environmental factors. The present case deals with microscopic and molecular diagnosis of *Murshidia linstowi* recovered from an elephant. A post-mortem examination of a free-ranging juvenile male elephant calf that had died of electrocution in Athagarh Wildlife Division revealed the presence of slender, whitish nematodes in the stomach. No gross lesions were noticed either in the site of predilection or any other internal organs. The average length of the parasites was 3.8cm. These parasites were collected for further gross as well as microscopic examination following routine parasitological techniques. Temporary mounts prepared after cleaning the nematodes in lactophenol were observed under a microscope. Morphological features such as a well-developed mouth collar, large and globular buccal capsule with fine tubercles, cone shaped oesophageal funnel, short bursa having indistinctly divided lobes and closely apposed ventral rays and stout spicules with club shaped tips bent dorsally corroborated with that of *M.linstowi* (male). Amplification of the rDNA from the internal transcribed spacer (ITS) region using universal nematode primers NC2 and NC5 revealed a product size of 870bp. The PCR product was subjected to sequencing followed by NCBI-BLAST which revealed 98% homology with *M. linstowi*. A phylogenetic study showed a maximum similarity with *M.linstowi* recovered from elephants in Kenya. This particular nematode species belonging to the family Strongylidae and sub-family Cyathostominae appears to be the first documented report in India.

Keywords: Gastrointestinal helminths, infection, nematode.

Helminths are ubiquitous across vertebrate taxa. They pose a threat to the welfare, management and conservation of captive as well as free-ranging elephants. Strongyles of the genus Murshidia reside in the alimentary canal of Indian and African elephants. *Murshidia* spp. affecting elephants include *M. linstowi* (Heinrich 2016; McLean et al. 2012), *M.* murshida (Ajitkumar et al. 2009; Chandra et al. 2018; Edwards et al. 1978; Muraleedharan 2016), *M.* falcifera (Ajitkumar et al. 2009; Chandra et al. 2018; Edwards et al. 1978; Matsuo and Supramah 1997),*M. longicaudata* (Heinrich 2016; McLean et al. 2012), *M. indica* (Ajitkumar et al. 2009; Muraleedharan 2016) and *M. Africana* (McLean et al. 2012). Murshidiasis in elephants has been reported from across the globe like Sri Lanka, Nigeria, Kenya, Burma, Indonesia and India. The present case report deals with molecular identification of *Murshidia linstowi* recovered from a free-ranging elephant calf that died of electrocution.

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History

A free-ranging juvenile, male elephant calf about 4½ years that had died of electrocution in Athagarh Wildlife Division (20.32^{0}N & 85.41^{0}E) was referred for investigation. The body condition of the elephant was almost normal. During post-mortem examination, two types of helminths (trematode and nematode) were recovered from its stomach. No gross lesions were noticed either in the site of predilection of the parasites or any other internal organs.

Materials and Methods

These parasites thus collected (Image1) were subjected to gross and microscopic examination following routine parasitological techniques and identified based on their features (Singh 2003).

Molecular diagnosis

The internal transcribed spacer (ITS) region within the rDNA provides a reliable marker to differentiate between several strongyles. Genomic DNA of the parasite was extracted using commercially available DNA mini kit (QIAGEN, Germany). According to the manufacturer's instructions, 25mg of the parasite was taken for the said purpose. The universal nematode primers NC2 (5'- TTAGTTTCTTTTCCTCCGCT-3') and NC5 (5'- GTAGGTGAACCTGCGGAAGGATCATT-3') were used for amplification (McLean et al. 2012). PCR was carried out in a 24µl reaction mixture containing2µl (640ng/µl)of genomic DNA, 2.4µl 10X PCR buffer, 2.4µl of 25mM $MgCl_2$, 0.16µl DNA polymerase, 1.2µl of each primer(10mM) and 2.4µl of dNTP mixture (2pmol). Amplification was preceded by a 10 minute polymerase activation step at 95ºC followed by 40 cycles of 45 sec each at 95ºC, 55ºC and 72ºC. A 5-min extension step at 72ºC concluded the reaction. The amplification products were subjected to electrophoresis on 1.5% agarose gel. The parasite sample was run in duplicates along with nuclease free water as negative control. The purified PCR products were subjected to sequencing for further identification. The similarity of the sequence with Genbank database submissions was carried out by using BLAST (http://blast.ncbi.nlm.nih.gov) (Altschul et al. 1990). The sequence was submitted to Genbank for generation of accession number. Additional 21 gene sequences were retrieved from the NCBI GenBank database (http://www.ncbi.nlm.nih.gov/). All the sequences were aligned and compared using ClustalW (http://www.ebi.ac.uk), with gaps and missing data eliminated from the dataset ("complete deletion option").There were a total of 707 positions in the final dataset. Molecular phylogenetic analysis was performed using MEGA 6.05. The best fit model for nucleotide substitution was selected from 24 models using MEGA 6.05 (Tamura et al. 2013) based on the minimum Bayesian Information Criterion (BIC) value (Nei and Kumar 2000; Schwarz 1798). The best fit nucleotide substitution model was used for testing the phylogenetic hypothesis using maximum likelihood method based on the Tamura-Nei model (Tamura and Nei 1993). The branch support for the correct location of branches was assessed through 1,000 bootstrap replicates.

Image 1. Helminths recovered from stomach of elephant.

Results and Discussion

Microsopic examination of the anterior end of the slender whitish nematode measuring about 3.8cm revealed the presence of a well-developed mouth collar, large and globular buccal capsule having fine tubercles and cone shaped oesophageal funnel (Image2). The posterior end consisted of a short bursa having indistinctly divided lobes and closely apposed ventral rays. Spicules were stout, straight with club shaped tips bent dorsally (Image3). Such morphological features corroborated with those of the male *M. linstowi* (Singh 2003). Molecular analysis showed a product size of 870bp (Image4). The sequencing results were compared with reference sequences of NCBI database using BLAST and 98% similarity was found with *M. linstowi* recovered from elephants in Kenya. The sequence was submitted to GenBank, with the accession number MK968095. Nucleotide substitution model with invariant sites (T92+I, BIC=3284.19, InL= -1282.61, I = 0.69) was chosen

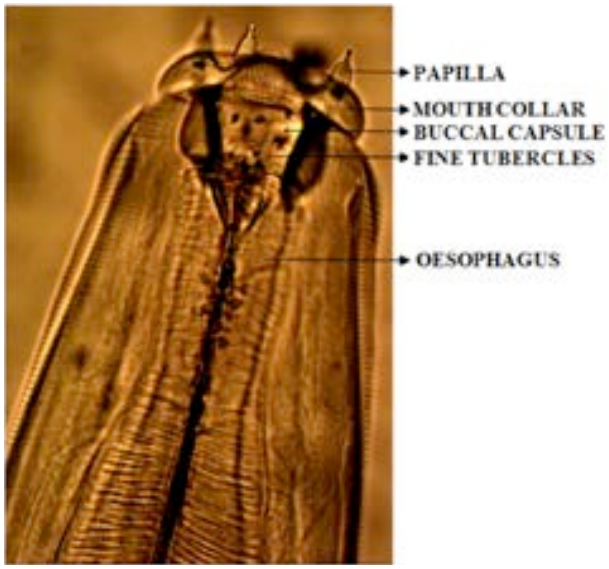

Image 2. Anterior end of *Murshidia linstowi* (male). © Sonali Sahoo

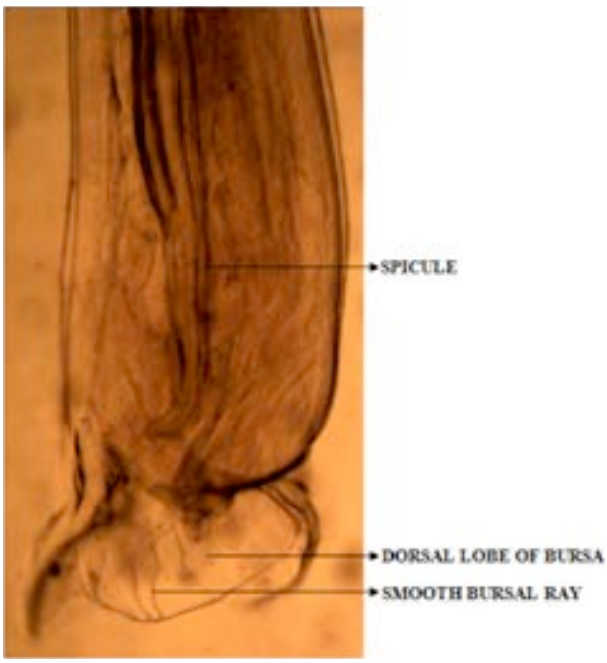

Image 3. Posterior end of *Murshidia linstowi* (male). © Sonali Sahoo

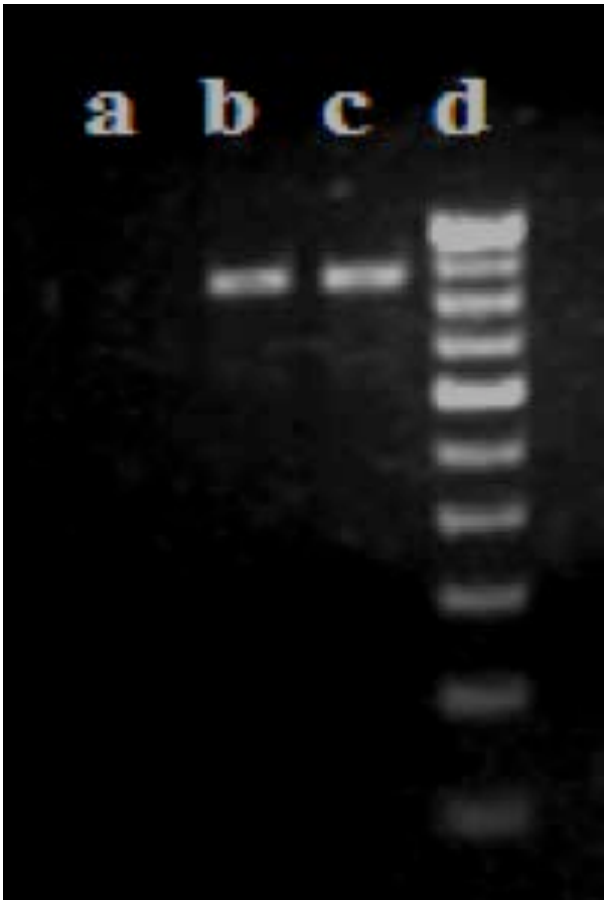

Image 4. Lane a—negative control | Lanes b & c—samples in duplicate (870bp) |Lane d—100bp DNA ladder. © Sonali Sahoo

as the best nucleotide substitution model (Tamura 1992). Nucleotide sequence of the sample and 21 reference sequences were used for the construction of a maximum likelihood phylogenetic tree (Figure 1). The bootstrap values shown in the nodes of the branches within the different clusters of *Murshidia* are relatively high. Therefore, the sample is likely to be *M. linstowi.*

Based on gross and microscopic examinations, the trematode was identified as *Pseudodiscus hawkesii* (Singh 2003). *P.hawkesi* measuring approximately 3.6–11mm in length and 2–6mm in breadth possessed the salient features like ventral mouth opening with oral suckers, well developed esophageal muscular bulb, lobed testes, sub-median ovary and coiled uterus.

Like other members of the subfamily Cyathostominae, *M.linstowi* probably has a direct life cycle. Eggs passed in the faeces hatch on the ground to release the first stage larva which subsequently develops into the third stage. These strongyles are inadvertently ingested by their hosts as infective third-stage larvae on vegetation (Newton-Fisher et al. 2006). Helminthic infections in many wild animals are often sub-clinical except in circumstances where the host-parasite equilibrium is being destabilized by stressors like concurrent infections, pregnancy, lactation and changes in climatic conditions. Clinical signs such as reduction in feed intake, edematous swelling on dependent parts of body, debility and reduction in body weight have been recorded in elephants suffering from murshidiasis (Tripathy et al. 1991). However, in the present case, no such clinical signs were evident. A single

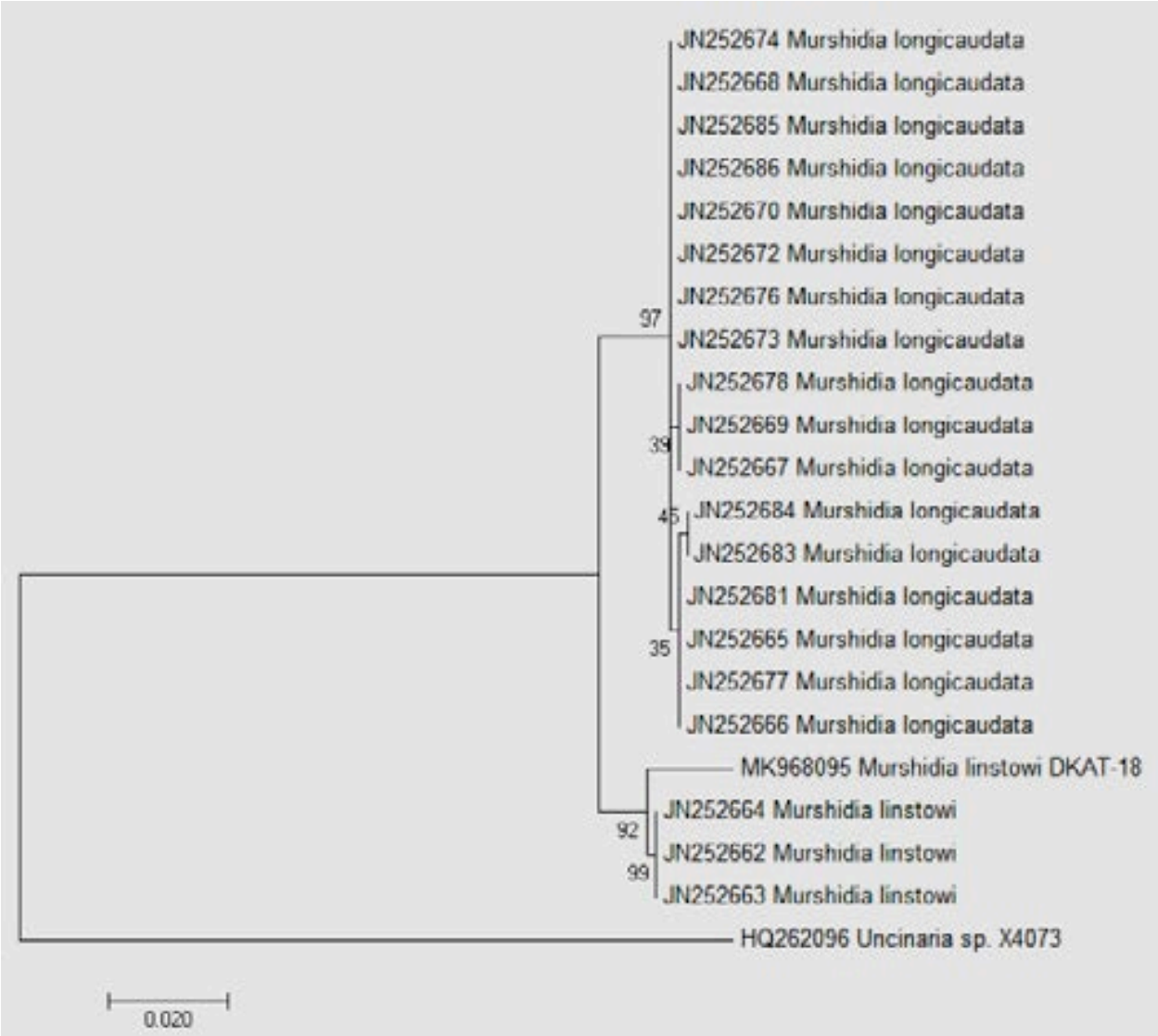

Figure 1. Evolutionary analysis of *M. linstowi* (DKAT-18) using 16s rDNA sequencing.

dose of fenbendazole at the rate of 5mg/kg body weight has been found to be successful against murshidiasis in elephants (Nei and Kumar 2000).

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SHORT COMMUNICATION

Parasite commonality at Swamp Deer (Mammalia: Artiodactyla: Cervidae: *Rucervus duvaucelii duvaucelii*) and livestock interface

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Abstract: Interactions between wildlife and livestock have increased over time with increased anthropogenic pressure on limited available natural habitats. These interactions have resulted in sharing of pathogens between the species resulting in impacting the wild animals' fitness and reproduction and further influencing their abundance and diversity. The spatial overlap between Swamp Deer and livestock was studied at Jhilmil Jheel Conservation Reserve (JJCR), Uttarakhand and Kishanpur Wildlife Sanctuary (KWLS), Uttar Pradesh in India, having different levels of interaction with livestock. The prevalence, load and commonality of gastro-intestinal parasites in the species was studied through coprological examination. Parasitic ova of *Strongyle* sp., *Trichostrongylus* sp., *Fasciola* sp., and *Moniezia* sp. *Amphistomes* were encountered in swamp deer and livestock from both the sites. The parasitic species richness and prevalence however, varied between JJCR and KWLS. The study recorded significant differences between the parasitic load in Swamp Deer with the eggs per gram of 487.5±46.30 at JJCR and 363.64±49.97 at KWLS at varying levels of livestock interactions.

Keywords: Coprology, eggs per gram, helminth, Jhilmil Jheel Conservation Reserve, Kishanpur Wildlife Sanctuary, wildlife.

BACKGROUND

Interactions between livestock and wildlife has increased in the recent past due to increased sharing of natural habitats resulting from increased demand for agriculture, grazing, water, and a diverse array of anthropogenic activities (Dobson & Foufopoulos 2001). These negative interactions result in competition for food, provide opportunity for pathogen sharing and may result in species hybridization (Foufopoulos et al. 2002; Lafferty 2003). Around 77% of livestock pathogens are multi-host with a majority affecting wild ungulates (Cleaveland et al. 2001). Parasitic infections and diseases in wildlife and at the livestock-wildlife interface have the potential to hamper conservation efforts by intensifying the ranges of host species (Dobson & Hudson 1986). A majority of these pathogens are opportunistic (Dobson & Foufopoulos 2001) with the ability to infect an unusually large number of host species. Though parasites rarely play a direct role in host extinction, they can significantly alter populations in conjunction with precipitating factors like habitat loss, habitat degradation, and climatic change (Purvis et al. 2000). There is mounting

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Image 1. Swamp Deer (*Rucervus duvaucelii duvaucelii* G. Cuvier, 1823) at Kishanpur Widllife Sanctuary.

theoretical and empirical evidence that parasites play an important role in influencing host populations through impacts on survival, reproduction, and trophic equilibria (Grenfell 1992).

Three subspecies of Swamp Deer, viz., *Rucervus duvaucelii duvaucelii* distributed in northern India, *R.d. branderii* in Kanha National Park in central India, and *R.d. ranjitsinhi* distributed in Assam (Poudel 2007; Sankaran 1990) have been recorded. The Swamp Deer is one of the most vulnerable species of deer from the Indian subcontinent as well as in the world, and is presently found only in isolated localities in northern and central India as well as in south-western Nepal (Qureshi et al. 2004). The population status is between 3,500 and 5,100 animals among which several meta-populations are found in patches in protected areas and outside where presence is not secure (Nandy et al. 2012).

The study focussed on Swamp Deer (Image. 1), a representative of specialized habitats and an important species of the swamp. The species is under threat due to loss of habitats, poaching, diseases etc. The habitat preference and seasonal movement pattern places the species in close proximity to livestock that results in sharing of pathogens and resultant disease. The species, like other cervids, is vulnerable to infection by gastro-intestinal parasites.

Methods

A rapid reconnaissance survey was carried out at Jhilmil Jheel Conservation Reserve (JJCR) and Kishanpur Wildlife Sanctuary (KWLS) to identify the intensive study are based on the presence of Swamp Deer and probable interaction with livestock. For the intensive study, Jhilmil Jheel area (JJ) of JJCR (Figure 1), and Jhadi Tal (JT) of KWLS (Figure 2) were selected where they had varying levels of interactions with livestock. JJ is considered as an area with high Swamp Deer-livestock interaction and more than 1,300 livestock have been reported to use JJCR on a daily basis (Tewari 2009). JT of KWLS on the other hand, is assumed to have minimal interaction between Swamp Deer and livestock as human settlement is present only in the northeastern side and the western side is bounded by the Kheri Branch canal of the Sharada canal system (Midha 2005). The population estimation of Swamp Deer conducted by Tewari & Rawat (2013) and Midha & Mathur (2010) included 320 and 400 individuals at JJ and JT, respectively.

Early morning dung pellet samples were collected from resting areas of Swamp Deer after they moved away for grazing at both the study sites. Simultaneously, random sampling was also performed to collect dung samples from livestock in both the study areas.

The sample size was calculated according to Thrusfield (1986) by considering 20% expected prevalence and 5% accepted error at 95% confidence interval using this formula: $N=1.962*Pexp(1-Pexp)/d2$; where, N=required sample; Pexp=expected prevalence; d=desired absolute precision. A total of 246 individual dung piles of Swamp Deer were selected by simple random sampling method whereas 20% of livestock population was sampled as suggested by Bogale et al. (2014). The inter-sample distance for Swamp Deer samples was maintained at 50cm distance, to ensure unique individual samples (Bogale et al. 2014). To determine the effective sample size for parasitic infection/ disease, the species accumulation curve (Cain 1938) was drawn by plotting the number of parasites present against the number of total samples collected for each study species at each study area. Randomization for the collected data was done on MS Excel followed by counting the number of parasite species present for each five samples.

Before collection, pellets were visually assessed for consistency and appearance. Six to eight fresh pellets weighing 20–30 g from each dung pile were collected in sample collection vials and preserved in 10% formaldehyde for further laboratory examinations. Pellets were observed qualitatively for consistency, color, odor, presence of mucous, blood, and parasite segments and observations made for each sample were recorded. Coprological examination for parasitic ova and the load was carried out using qualitative tests (employing floatation and sedimentation techniques) and quantitative tests (employing modified Mc master technique to assess the eggs per gram (EPG) of dung) as

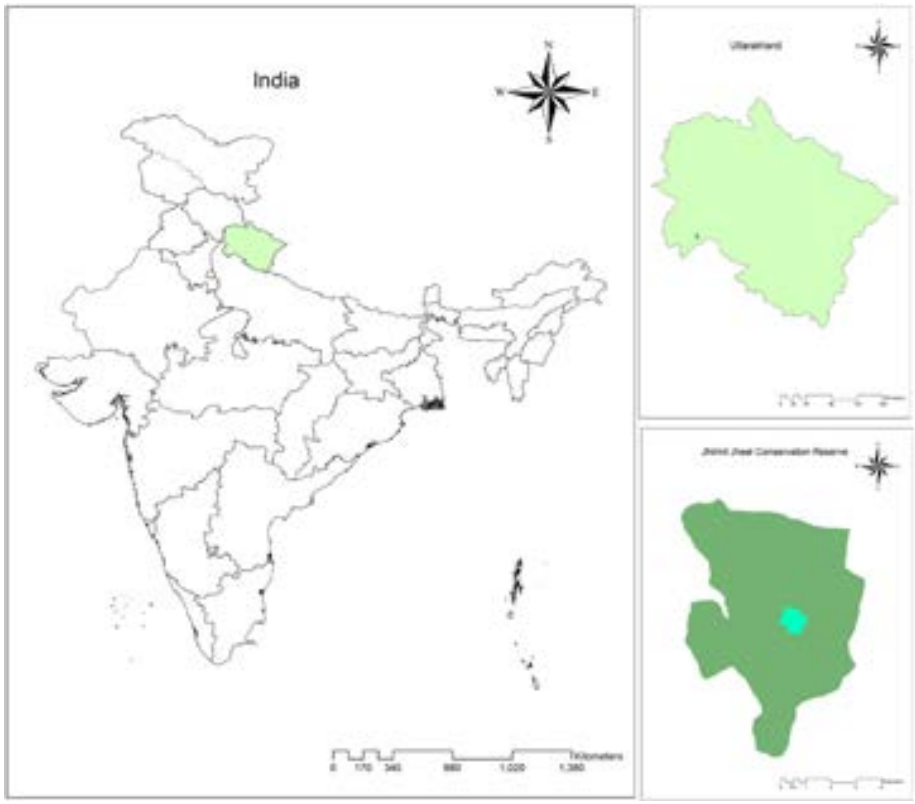

Figure 1. Map showing the location of Jhilmil Jheel Conservation Reserve in Uttarakhand.

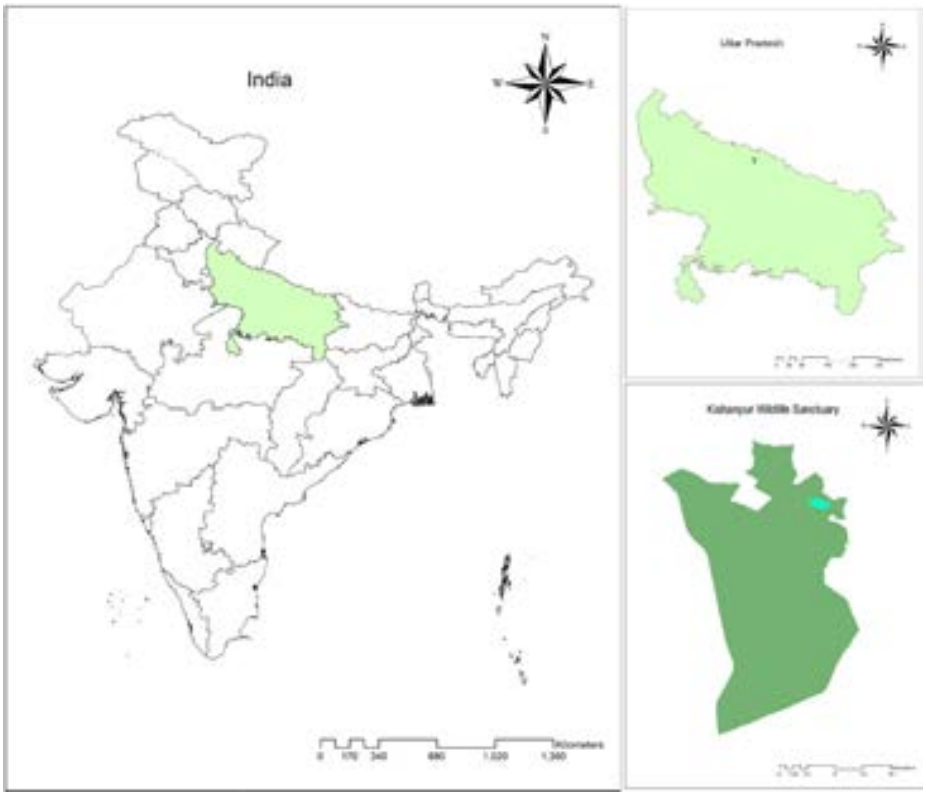

Figure 2. Map showing the location of Kishanpur Wildlife Sanctuary in Uttar Pradesh

described by Soulsby (1982). Parasite egg identification was based on Soulsby (1982). The entire study period was for six months from December 2014 to May 2015.

The prevalence of parasitic infection was calculated in the two populations as the number of individuals infected in the total individuals sampled in a given area and calculated as

Prevalence percentage = (Number of positive sample (Individuals)/Number of samples tested) X 100 (Thrusfield 1986).

The species-wise parasitic prevalence in total Swamp Deer and livestock population was derived as

Species-wise parasitic prevalence = (Individuals infected with particular parasite/Total positive sample) X 100.

The parasitic load was estimated as eggs per gram (EPG) of dung and the egg count for positive samples were multiplied with 200 for nematode and cestode, and by 50 for trematodes and later, average mean EPG was calculated for each studied species at both study areas (Soulsby 1982; Shrivastav & Singh 2004). Significant difference between the average parasitic load of Swamp Deer in between the population of JJ and JT was tested using Mann-Whitney U test by software SPSS (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc).

Results and Discussion

Of the total samples collected and screened for parasitic ova, the overall prevalence of parasitic ova in the Swamp Deer population at JJ and JT were 15.38% and 12.69%, respectively, whereas the overall parasitic prevalence in livestock population at JJ and JT were 95.41 % and 60%, respectively. The overall prevalence rate observed in the study for Swamp Deer (15.28 in JJ and 12.69 in JT) was less as compared to those reported by Tiwari et al. (2009) (51.03%) for the study carried out at Kanha Tiger Reserve and Chakraborthy & Islam (1996) (21.85%) for the study in Kaziranga National Park. These may be attributed to sampling restricted to a shorter period (winter months) with environmental conditions that limit survival of parasites outside the host.

Based on the laboratory analysis, the presence of nematode, trematodes, and cestodes was confirmed from Swamp Deer as well as livestock in both the areas and represented parasitic ova belonging to group *Strongyle*, *Trichostrongyle*, *Moniezia*, *Fasciola*, and *Amphistome* (Image 2). The commonality of genus of parasites observed in Swamp Deer also correlated with the observations made by Tiwari et al. (2009) who carried out a similar study in Kanha Tiger Reserve.

In JJ, the *Strongyle* group was the most prevalent parasitic ova (67%) followed by *Amphistomes* (28%) and *Fasciola* (5%) for Swamp Deer and *Amphistome* were the most prevalent at 91%, followed by *Strongyle* (6%) and *Trichostrongyle* (1%), *Moniezia* (1%), *Fasciola* (1%) in livestock.

In JT, *Amphistome* was the most prevalent at 45%, followed by *Strongyle* (45%), *Fasciola* (5%), *Moniezia* (5%) and *Trichostrongyle* (3%) in Swamp Deer whereas *Strongyle* was the most prevalent at 49%, followed by *Amphistome* (41%), *Moniezia* (4%) and *Fasciola* (2%) in livestock.

The findings of the present study varied from those reported by Tiwari et al. (2009) who documented the prevalence percentage of *Strongyle* sp. to be maximum at 98.71% followed by *Amphistomes* (88.65%), *Strongyloides* (32.21%), *Trichuris* sp. (18.55%), *Moniezia expansa* (11.85%), *Coccidia* (7.47%), and *Moniezia benedeni* (4.63%) in Barasingha in Kanha Tiger reserve.

The load of different parasitic ova in the Swamp Deer population at both sites revealed an overall mean EPG of 487.5±46.30 at JJ and 363.64±49.97 at JT. There was a significant difference in parasitic load between the two study sites ($p<0.01$, Mann–Whitney U test). The mean EPG of dung for *Strongyle* sp. was 642.85 ± 33.10 and 544 ± 53.15 at JJ and JT, respectively. Though *Trichostrongylus* sp. *and Moniezia* sp. were absent in JJ, the EPG of 200 was recorded for both the species at JT. The overall mean EPG for *Fasciola* was 100 ± 28.86 and 50 at JJ and JT, respectively, whereas the mean EPG for *Amphistome* was 109.09 ± 6.09 and 96.87 ± 5.53 at JJ and JT, respectively. The higher values of EPG at JJ may be attributed to higher livestock presence and interaction. Although the Swamp Deer sampled in this study visibly appeared healthy, the high prevalence of some of the studied pathogens may have significant consequences for their population dynamics.

Conclusion

There have been only sporadic reports and reviews of parasitic diseases in cervids and limited systematic studies have been carried out to establish the cause and spread of disease (Watve & Sukumar 1995; Dharmarajan et al. 2003, 2004, 2005; Jog & Watve 2005). This study provided an overview of the prevalent parasites in the wild and domestic animals at the wildlife-livestock interface limited to a grassland system. The parasitic infection in swamp deer and their sympatric livestock appeared qualitatively and quantitatively parallel denoting the fact that the infection is being maintained in the environment through interaction between these

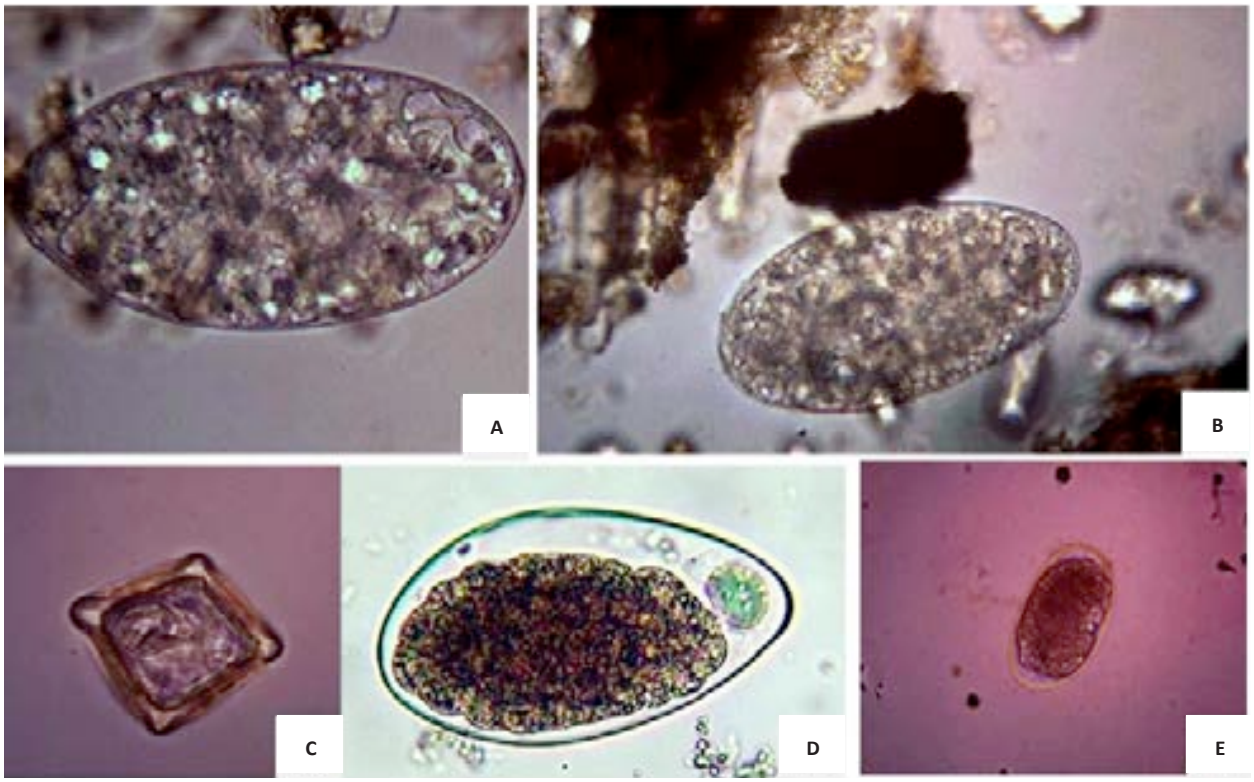

Image 2. Helminth eggs under microscope. Parasitic ova encountered during the study: A—*Fasciola* (10X)| B—*Amphistome* (10X)|, C—*Moniezia* (40X) D—*Trichostrongyle* (40X) | E—*Strongyle* (40X).

animals. These parasitic infections may be exposing the Swamp Deer to a number of other diseases and may be one of the factors contributing to decline in their population. Even though the study was conducted only for a short period of time, it could highlight the presence of parasitic diseases at the interface.

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SHORT COMMUNICATION

Prevalence and seasonal variation of gastrointestinal parasites among captive Northern Pig-tailed Macaque *Macaca leonina* (Mammalia: Primates: Cercopithecidae)

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Abstract: A study on the prevalence and seasonal variations of gastrointestinal parasites of 12 captive Pig-tailed Macaques *Macaca leonina* housed at Aizawl Zoological Park, Mizoram, India, was conducted. Fresh stool samples were collected on a monthly basis from the study animals was grouped for two seasons—summer (April–June 2017) and monsoon (July–September 2017). Samples were stored in 10% formalin until further processing. Three methods—direct smear, faecal floatation, and faecal sedimentation were used. Two categories of parasites—protozoa and nematodes were recorded. *Balantidium coli*, a protozoa, *Strongyle*, *Ascaris lumbricoides*, *Trichiuris trichiura*, and nematode parasites were recorded in different stages. Out of 71 samples analysed, 63 samples (88.73%) were positive with ova of gastrointestinal parasites. The prevalence of *Balantidium coli* was highest with 38.23% and 56.75%, followed by Strongyle 35.29% and 37.83% in summer and monsoon season, respectively. A variation on the prevalence of gastrointestinal parasites was assessed using chi squared tests between monsoon season and summer season. Variation was found to be significant (χ^2=20.569, P<0.05 and χ^2=10.857, P<0.05). The overall prevalence of gastrointestinal parasites was higher during monsoon season (91.89%) than summer season (85.29%).

Keywords: Aizawl Zoological Park, *Ascaris lumbricoides*, *Balantidium coli*, India, Mizoram, Strongyle, *Trichiuris trichiura.*

Non-human primates are susceptible to a variety of diseases caused by infection with gastrointestinal parasites, both in the wild and in captivity (Kuntz 1982). Captive animals are supposed to have low prevalence of parasites as anti-helminthic measures are practiced, however, infestation may be more due to unhygienic conditions of cages. Crowding of animals in cage, type of food and feeding practices are key factors in the development of endoparasites in zoo animals (Malan et al. 1997; Mul et al. 2007; Sanchez et al. 2009). The majority of primate pathogens culminate in chronic, sub-lethal infections (Goldberg et al. 2008) and parasite infections with low immune system can trigger deterioration of health (Glaser & Kiecolt-Glaser 2005; Coe 2011). Gastrointestinal parasite infected animals exhibit symptoms like watery diarrhea, hemorrhage, and dysentery; the animals may also develop renal infections that eventually lead to death (Levecke et al. 2007). Parasite load may affect the fitness of the host, influencing the survival and reproduction of the infected individuals (Boyce 1990; Hudson 1992; van Vuren 1996; Hilser et al. 2014). Knowledge about the

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profile of gastrointestinal parasites and their intensity in primates may help the zoo managers in developing better management plans to maintain the health of this threatened species, and to ensure local survival. This study is an attempt on captive Pig-tailed Macaque *Macaca leonina* to understand the parasitic profile of this threatened primate species so that the zoo authorities may undertake appropriate measures for prevention of parasite infection for this species and also for primates in general.

Materials and Methods

Study site

The study was conducted at Aizawl Zoological Park that covers an area of 65ha and is situated 14km away from Aizawl, the state capital. The zoo maintains seven species of primates, which includes four species of Vulnerable (VU) primates, such as, Stump-tailed Macaque *Macaca arctoides*, Northern Pig-tailed Macaque *Macaca leonina*, Bengal Slow Loris *Nycticebus bengalensis*, and Capped Langur *Trachypithecus pileatus*, one Near Threatened (NT) species, Assamese Macaque *Macaca assamensis*, one Endangered (EN) primate, Western Hoolock Gibbon *Hoolock hoolock*, and one Least Concern (LC) primate, Rhesus Macaque *Macaca mulatta*.

Subjects

The Northern Pig-tailed Macaques study group included a total of 12 individuals, seven males and five females. They live in an enclosure of 850m^2 area with two adjacent indoor rooms which can be opened or closed by sliding doors. They are fed with fruits and vegetables every day. Water is available ad libitum. For the control of parasitic infection, piperazine hydrazine liquid 61% is used by the zoo authorities. The piperazine hydrazine liquid is mixed with water which is given to the monkeys for drinking. This treatment is done once in three months as recommended by the veterinarian.

Faecal sample collection

This study was conducted during April 2017–September 2017. Fresh stool samples were collected each month from the study group and grouped into two seasons summer (April–June 2017) and monsoon (July–September 2017) for meaningful inference. Animals were in captive conditions, hence monthly variations were not cognizable. Samples were examined macroscopically for the presence of larval or adult of various parasites at different stages. Samples were collected in the morning hours and were stored in 10% formalin at the sampling site for further processing as per the procedures mentioned by Gillespie (2006). The collection tubes labeled with date and time of collection were shaken vigorously to homogenize sample and storage solution.

This study was undertaken with the permission of the Chief Wildlife Warden, Department of Environment, Forest and Climate Change under the permission number A.33011/4/2011-CWLW/Vol.II/388-89.

Sample processing

Three methods as recommended by Gillespie (2006) were used for the identification of parasitic infection, i.e., direct smear, faecal floatation, and faecal sedimentation

Direct Smear: A thin smear of faecal material with normal saline was prepared on a slide and observed under the microscope.

Faecal floatation: Approximately 1g of faeces was placed into a 15ml centrifuge tube. The tube was filled 2/3rd with de-ionised water and homogenized with a wooden spatula, then centrifuged for 10min at 1,800rpm. The supernatant was decanted and the faeces was re-suspended in sodium nitrate ($NaNO_3$) solution. The tube was filled to the meniscus with $NaNO_3$ and a cover slip was placed on the mouth of the tube and left for 10min. The cover slip was removed and placed on a labelled slide. Single slide for each individual sample was observed under a microscope with 10X and 40X magnifications. Presence of parasitic helminths and protozoa were observed and photographed.

Faecal sedimentation: One gram of the preserved faecal sample was homogenized in a centrifuge tube, topped up and thoroughly mixed with 7–10 ml of 10% formal saline solution which also served as the fixative. The resulting suspension was strained into a clean centrifuge tube using a fine sieve to remove debris. Three milliliters of diethyl ether was then added. The mixture was stoppered, mixed, and centrifuged for 3min at 2,000rpm. Debris and fat which formed a floating plug were dislodged using an applicator stick and the supernatant was discarded. Using a Pasteur pipette, a drop each of the remaining sediment was transferred to a clean glass microscope slide to make a wet smear. Lugol's iodine solution (0.15%) was used to stain the slide. Sediments were further screened and analysed for identification of parasites and their different stages.

Chi-square test was used to assess the variation on the prevalence of each gastrointestinal parasite between winter and summer seasons. Chi-square test was carried out with SPSS version 18.0.

Results

The study animals were found to be infected with two major groups of parasites: protozoa and nematodes. Four species of parasites, namely, *Balantidium coli* (protozoa), and *Strongyle*, *Ascaris lumbricoides,* and *Trichiuris trichiura* (nematodes), were recorded. Photos of the ova of all species recorded are given on Image 1. Out of the total 71 samples analyzed during the study, 63 samples (88.73%) were found to be positive with ova of gastrointestinal parasites, however, seasonal variations in the rate of infestation and different parasite species recorded also varied. In summer, out of 34 faecal samples, 85.29% were infected with parasites. In this season, protozoan infestation was found to be more (38.23%) and among nematodes, infection with *Trichiuris trichiura* (35.29%) was highest, followed by *Strongyle* (26.47%), and *Ascaris lumbricoides* (23.53%). The overall prevalence of gastrointestinal parasites was higher during monsoon season (91.89%) than summer season (85.29%). In the monsoon season, the rate of infection with *Balantidium coli* was high (56.75%), followed by *Strongyle* and *Trichiuris trichiura* (37.83% and 37.83%, respectively) and *Ascaris lumbricoides* (27.02%). Seasonal comparison of prevalence (%) of all four types of parasites is given in Figure 1. The prevalence of *Balantidium coli* was also highest in both the seasons, followed by the whipworm *Trichiuris trichiura*.

On comparing the prevalence of infection between the summer and monsoon seasons, it was found that infection with *Balantidium coli* and *Strongyle* was significantly higher during monsoon season than summer season (χ^2=20.569, P<0.05 and χ^2=10.857, P<0.05, respectively). There was, however, no significant variation on the prevalence of *Ascaris lumbricoides* and *Trichiuris trichiura* between the two seasons (χ^2=3.611, P=0.164 and χ^2=3.782, P=0.151, respectively).

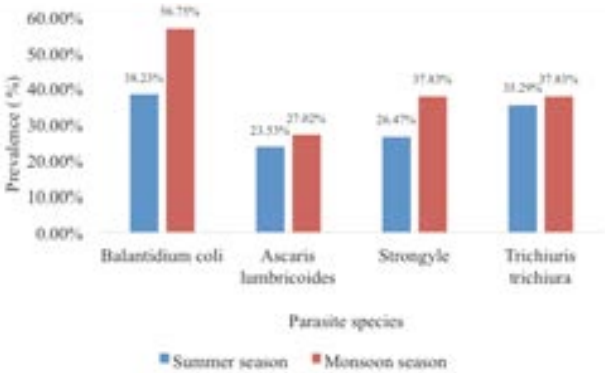
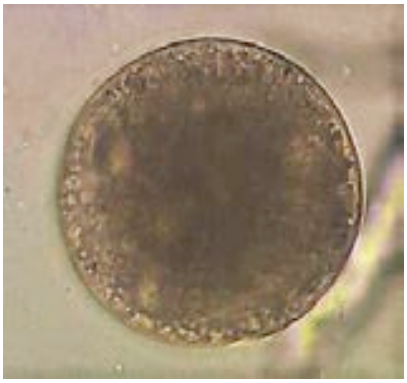
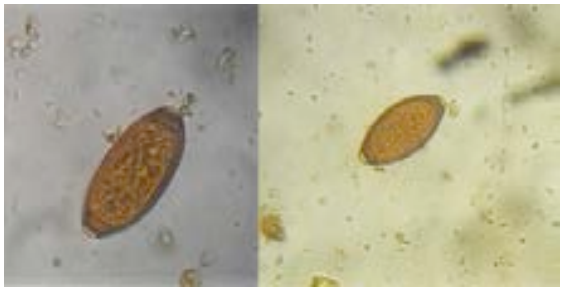


Figure 1. Comparison of the prevalence of gastrointestinal parasites during summer and monsoon season.

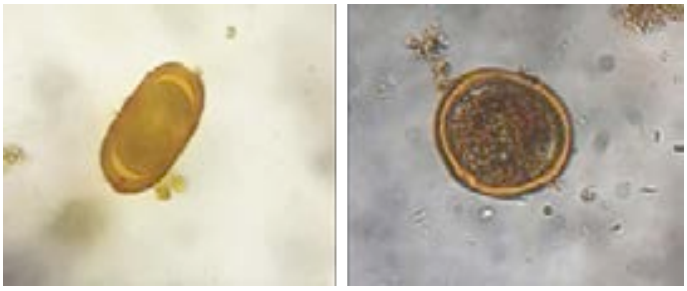
Ova of *Strongyle*



Ova of *Balantidium coli*



Ova of *Trichiuris trichiura*



Ova of *Ascaris lumbricoides*

Image 1. Different gastrointestinal parasites reported in Pig-tailed Macacque.

Discussions

Several parasitic infections have been reported in non-human primates, both in captivity (Levecke et al. 2007; Cordon et al. 2008; Nath et al. 2012; Barbosa et al. 2015; Margono et al. 2015) and in the wild (Legesse & Erko 2004; Parr 2013; Kouassie et al. 2015). The prevalence observed in the present study (88.73%) was higher than that reported by Opara et al. (2010) in captive animals, with prevalence rates of 62.5% and 61.5%, respectively. Parasitic diseases are reported to be common to zoo animals in tropical countries due to the climatic factors that favor the development of parasites such as light, temperature, and humidity (Opara et al. 2010). The two groups of parasites were also reported in Belgium Zoo in prosimians, old world monkey, new world monkeys, and some apes (Levecke et al. 2007). The protozoa and nematodes are highly prevalent even in wild non-human primates (Kouassi et al. 2015). The present study also indicates high prevalence of protozoa (*Balantidium coli*) in both the seasons as compared to nematodes (Figure 1), which is similar to the study conducted by Levecke et al. (2007) in Belgium on captive primates. Trematodes and cestodes were not detected in this study. This could be because these parasites require an intermediate host for their transmission and that are less likely in the captive environment (Atanaskova et al. 2011).

Attendants of enclosures of these animals could act as vehicles for cross transmission. Also, the animals serve as potential reservoirs that could transmit gastro-intestinal parasites to zoo keepers and possibly to visitors. This study further shows the need for an anti-helminthic program such as early season treatments to prevent infection in animals under captivity, regular passive surveillance for parasitic infections, and effective treatment programs. Moreover, it has been observed that confinement of wild animals in zoo makes them more prone to different parasitic infections despite proper attention for feeding, water, and maintenance of hygiene in captivity (Kashid et al. 2002). The nematodes and some coccidian parasites have a direct life cycle, without any intermediate host and are transmitted by feco-oral route through contaminated feed, water, and soil and have the potential to accumulate in a captive environment (Thawait et al. 2014). The environmental contamination could be through contaminated water or fodder, and zoo workers have also been reported to play a role in transmission by acting as vectors and transmitting parasites through their shoes, clothes, hands, food, or with working tools (Adetunji 2014; Otegbade & Morenikeji 2014). Based on this study, it is recommended that upgraded and more effective regular preventive as well as prophylactic measures are needed to be included in the management schedule of these animals at regular interval. Physical and chemical based hygiene are also needed as a part of management programs for captive animals.

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SHORT COMMUNICATION

New record of *Tulostoma squamosum* (Agaricales: Basidiomycota) from India based on morphological features and phylogenetic analysis

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Abstract: *Tulostoma squamosum* is reported for the first time from India. A comprehensive macro-morphological description, field photographs along with microscopic observations, and comparisons with morphologically similar and phylogenetically related taxa are provided. Nucleotide sequence comparison and an estimation of evolutionary divergence between *Tulostoma squamosum* sequences across different geographic origin are also provided.

Keywords: Evolutionary divergence, new record, nrDNA ITS, phylogenetic analysis.

The genus name *Tulostoma* was coined by the African mycologist Christiaan Hendrik Persoon in 1801 for the taxa possessing characters like two layered peridium and a woody stalk. The genus is cosmopolitan in distribution comprising of ca. 140 accepted species and mostly found across habitats like sandy soils, forests, pastures, on road sides etc. (Wright 1987; Lima & Baseia 2018).

During repeated field trips by the authors for exploring the hidden macrofungal diversity of West Bengal across different geographical zones since last two decades, a specimen was collected and identified as *Tulostoma squamosum* (J.F. Gmel.) Pers. from Darjeeling Hills. Geographically, Darjeeling Hills falls under the eastern Himalayan range and encompasses an area of 524,190km^2 (21.95–29.45 ^{0}N & 82.70–100.31 ^{0}E). The forest of the region is mostly dominated by plants like *Castanopsis* sp., *Quercus* sp., *Cryptomeria japonica*, *Alnus* sp., *Magnolia campbellii, Lithocarpus* sp., *Abies* sp., and large *Rhododendron* spp. (State Forest Report 2011–2012; Paloi et al. 2015).

Currently, there are 24 reported species of *Tulostoma* from India, viz.: *T. albiceps* Long & S. Ahmad, *T. albocretaceum* Long & S. Ahmad, *T. amnicola* Long & S. Ahmad, *T. balanoides* Long & S. Ahmad, *T. cineraceum* Long, *T. crassipes* Long & S. Ahmad, *T. evanescens* Long & S. Ahmad, *T. exitum* Long & S. Ahmad, *T. hygrophilum* Long & S. Ahmad, *T. inonotum* Long & S. Ahmad, *T. membranaceum* Long & S. Ahmad, *T. mussooriense* Henn., *T. operculatum* Long & S. Ahmad, *T. parvissimum* Long & S. Ahmad, *T. perplexum* Long & S. Ahmad, *T. pluriosteum* Long & S. Ahmad, *T. psilophilum* Long & S. Ahmad, *T. puncticulosum* Long & S. Ahmad, *T. pygmaeum* Lloyd, *T. sedimenticola* Long & S. Ahmad, *T. subsquamosum* Long & S. Ahmad, *T. volvulatum*

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Borshchov var. *volvulatum*, *T. vulgare* Long & S. Ahmad, and *T. wightii* Berk. (Wright 1987). The present study reports *Tulostoma squamosum* for the first time from India based on morphological as well as molecular data along with comparison of morphologically and phylogenetically related species. In addition, the sequence of the Indian collection was compared to the sequences, deposited from other regions of the world, to find out the changes of the nucleotide positions and evolutionary divergence.

Materials And Methods

Morphological protocols

Fresh basidiomata were collected from Darjeeling Hills of West Bengal, India during the month of July 2019. Field photographs of the fresh basidiomata were taken at the field with Canon EOS 1200D (Canon, India) camera. For colour notations, Kornerup & Wanscher (1978) was followed. Collected basidiocarps were dried with a field drier at 50–60 °C.

For microscopic observations, free-hand sections were prepared from the dried basidiomata and 5% KOH solution was used to revive those hand-made sections. After staining with Congo red, and Melzer's reagents, sections were observed with Dewinter 'crown' trinocular microscope (Dewinter Optical Inc., New Delhi). Spores were measured with atleast 20 measurements from each of the collected three basidiocarps. In spore statistics, values in parentheses represent minimum or maximum measured values; X_m denotes the mean of the spore length by its width (± standard deviation); Q represents range variation of the quotient of basidiospore length/width ratio in any one basidiospore; Q_m, the mean of Q-values (± standard deviation); and n, the total number of spores measured. For future reference, voucher specimens were deposited in the Calcutta University Herbarium (CUH).

DNA extraction and PCR amplification

Genomic DNA was extracted from the dried fruitbodies following Dutta et al. (2018). PCR amplification of the nuclear ribosomal internal transcribed spacer sequence (nrITS) region was performed using fungal universal primers pair ITS1 and ITS4 (White et al. 1990) on an Applied Biosystems 2720 automated thermal cycler using the thermal profile as described by Dutta et al. (2018). After purification by QIAquick® Gel Extraction Kit (QIAGEN, Germany), PCR products were subjected to automated DNA sequencing on ABI3730xl DNA Analyzer (Applied Biosystems, USA) using the same primer pairs used for the amplification of rDNA ITS region.

The newly generated sequence of *T. squamosum* was then edited using BioEdit v7.0.5 software (Ibis Therapeutics, Carlsbad, CA) and used for a BLAST search in the NCBI database. Altogether 36 nrDNA ITS sequences of *Tulostoma* representing 28 species were chosen for the phylogenetic analyses based on the BLAST search and the previous study of Jeppson et al. (2017). *Lycoperdon perlatum* Pers. and *Calvatia gigantea* (Batsch) Lloyd were selected as out-group taxa for rooting purpose following Jeppson et al. (2017).

Sequence alignment and phylogenetic analyses

The nrITS data set was aligned using MAFFT v.7.402 (Katoh & Standley 2013) on XSEDE in the CIPRES web portal (http://www.phylo.org/portal2/) (Miller et al. 2010). The aligned datasets were then imported to MEGA v.7.0 (Kumar et al. 2016) for additional manual adjustments.

Statistical selection for the best fit model of nucleotide substitution for the dataset was performed by jModelTest2 (Darriba et al. 2012) on XSEDE using CIPRES web portal. For the given dataset, GTR+G model was selected as the best fit model for the phylogenetic analyses based on the lowest BIC values of 12712.992931.

Maximum likelihood bootstrapping analyses were performed with RAxML-HPC2 v. 8.2.12 (Stamatakis 2006), using the model parameters as suggested by jModelTest2 on the CIPRES NSF XSEDE resource with bootstrap statistics calculated from 1,000 bootstrap replicates.

Bayesian inference (BI) of the phylogeny were carried out using MrBayes v.3.2.2 (Ronquist et al. 2012) using metro-polis-coupled Markov chain monte carlo analyses (Geyer 1991). The general time reversible (GTR) model was employed with gamma-distributed substitution rates. Markov chains were run for 10^6 generations, saving a tree every 100^{th} generation. Default settings in MrBayes were used for the incremental heating scheme for the chains (3 heated and 1 cold chain), branch lengths (unconstrained: exponential (10.0)), partition-specific rate multiplier (fixed (1.0)), and uninformative topology (uniform) priors. After burn in initial 25% trees, MrBayes was used to compute a 50% majority rule consensus of the remaining trees to obtain estimates of the posterior probabilities (PPs) of the groups. Maximum likelihood bootstrap (MLBS) and Bayesian posterior probabilities (PP) values over 50% and 0.50 are reported in the resulting tree.

Nucleotide sequence comparison of *T. squamosum* across different geographic origins

Based on the earlier published studies (Hussain et al. 2016, Jeppson et al. 2017), three well representative sequences of *Tulostoma squamosum*, deposited based on the collections made from different geographic regions, were procured from the NCBI GenBank nucleotide database and were aligned with the newly amplified Indian collection of *T. squamosum* using MUSCLE (Edgar 2004). The nucleotide sequence comparison was accomplished from this alignment for finding out the positional dissimilarities in the entire nrDNA ITS sequence.

Estimates of evolutionary divergence between *Tulostoma squamosum* sequences

Estimation of evolutionary divergence was performed between four sequences of *T. squamosum*, one from the present Indian collection (this study) and the remaining three from France (KU519097), Pakistan (KT285883), and Spain (KU519096). Evolutionary divergence analysis was carried out in MEGA v.7.0 (Kumar et al. 2016) using the Kimura 2-parameter model (Kimura 1980) where all positions containing gaps and missing data were eliminated.

Results

Phylogenetic analyses

Sequencing product of the Indian collection of *Tulostoma squamosum* ranged 658 nucleotides. ITS sequences were aligned and the ends trimmed to create a dataset of 726 base pairs of which the final alignment had 420 distinct alignment patterns. Bayesian analyses reached a standard deviation of split frequencies of 0.002 after 10^6 generations and the credible sets of trees included 7,535 trees after excluding the preliminary 25% trees as the burn-in. The trees generated using the ML and Bayesian analyses were identical in topology. Therefore, only the phylogenetic tree generated using ML analysis (InL = -6084.179608) is shown in Figure 1.

Nucleotide sequence comparison

Comparison made from the alignment of an entire nrDNA ITS region of the Indian sequence of *Tulostoma squamosum* along with the three deposited sequences of the same taxon from France (KU519097), Pakistan (KT285883), and Spain (KU519096) reveals that the Indian collection differs from Pakistani collection by eight nucleotide positions, France and Spain collections by five nucleotide positions each (Table 1).

Addition of two adenine nucleotides were also observed at the 584 and 585 nucleotide positions for the Pakistani sample when compared to the present Indian as well as those of the France and Spain samples. Besides, the Indian collection of *T. squamosum* shows insertion of Thymine nucleotide at the 486 nucleotide position when compared to that of the France, Spain, and Pakistan collections.

Estimation of evolutionary divergence between *Tulostoma squamosum* sequences

Estimation of Evolutionary Divergence of four sequences of *Tulostoma squamosum* from India (this study, MN809136), France (KU519097), Pakistan (KT285883) and Spain (KU519096) involved a total of 301 positions in the final aligned dataset. The present Indian sequence of *T. squamosum* varies by 3.1% from the Pakistani sequence and by 2% from the sequences deposited from France and Spain respectively (Table 2). The Pakistani *T. squamosum* sequence, however, showed variation of 1.7% each from France and Spain *T. squamosum* sequences (Table 2).

Taxonomy

***Tulostoma squamosum* (J.F. Gmel.) Pers.**, Syn. meth. fung. (Göttingen) 1: 139 (1801) (Image 1)

Spore-sac 20–30 mm diam., globose, smaller compared to length of stalk. Exoperidium thin, membranous, greyish-orange (5B3, 5B5-6) towards mouth, elsewhere yellowish-brown (5D5-6; 6E6-8), smooth to obscurely reticulate. Endoperidium

Table 1. Comparison of the entire nrDNA ITS sequences (641 nucleotides) between the Indian collection of *Tulostoma squamosum* (in bold front) and of three sequences of Tulostoma squamosum deposited in GenBank database from France, Pakistan and Spain.

Name of the taxon	Geographic origin	Positions in the ITS 1+2 alignment (641 nucleotides)								
		448	502	503	505	556	610	614	615	635
T. squamosum (MN809136)	India	T	T	A	T	T	C	T	T	A
T. squamosum (KU519097)	France	C	C	A	A	T	C	T	C	G
T. squamosum (KT285883)	Pakistan	C	T	G	A	A	A	C	C	G
T. squamosum (KU519096)	Spain	C	C	A	A	T	C	T	C	G

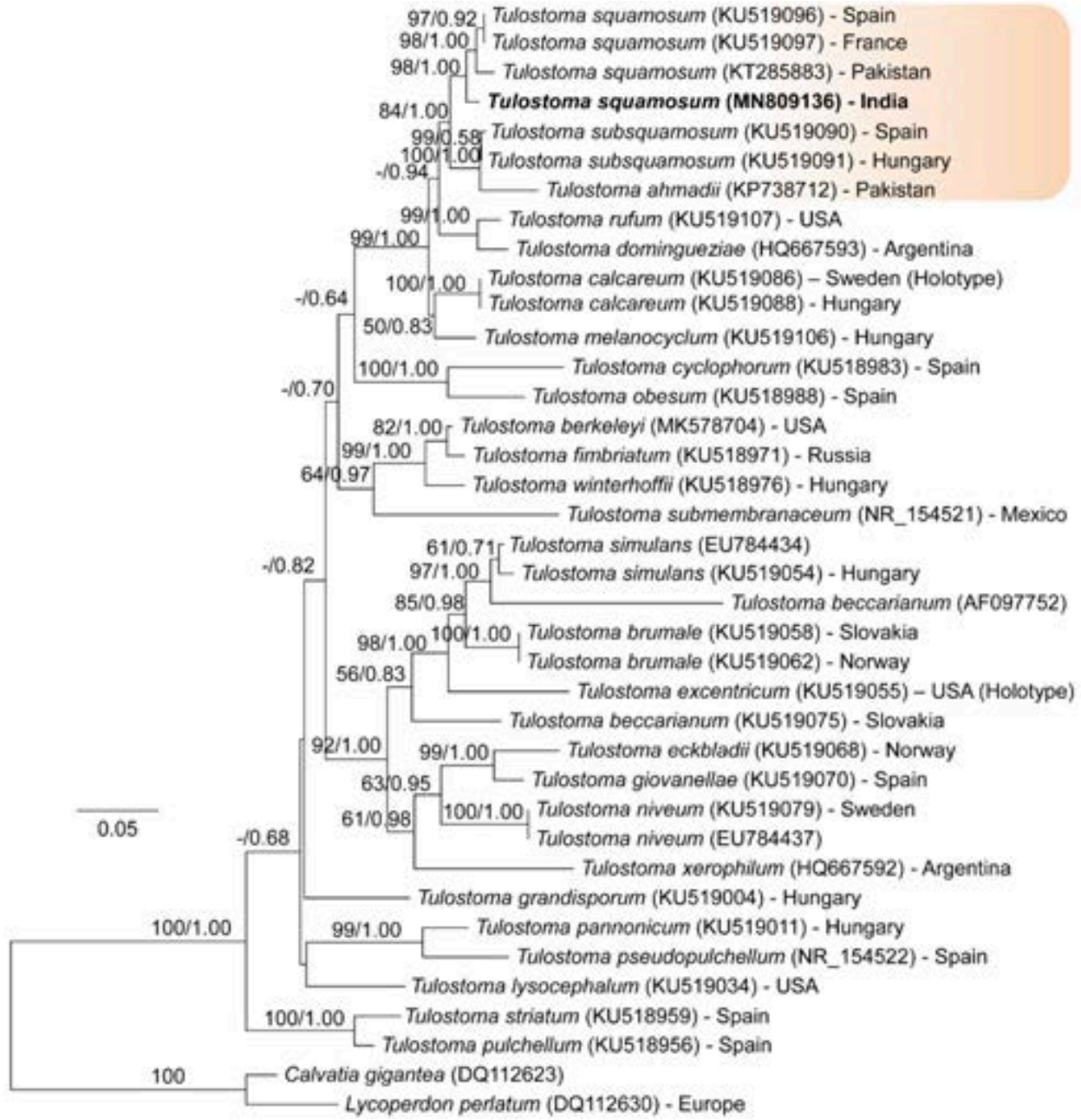

Figure 1. Maximum likelihood tree (InL = -6084.179608) generated using GTR+G model of nucleotide evolution based on newly generated sequence of *Tulostoma squamosum* and acquired nrDNA ITS sequences based on the previous study of Jeppson et al. (2017). *Lycoperdon perlatum* and *Calvatia gigantea* were selected as out-group taxa for rooting purpose following Jeppson et al. (2017). Numbers to the left of / are ML bootstrap percentages (MLBS), and those to the right are Bayesian posterior probabilities (PP). MLBS values ≥ 50% and PP values ≥ 0.50 are shown above or below the nodes. Scale bar represents the expected changes per site.

slightly paler, smooth. Mouth prominent, 1mm diam., somewhat tubular, peristome pale orange (6A3). Socket distinctly separated from stem. Gleba light ochraceous. Stalk 100–120 × 3–6 mm, brown (7D8), sub-scaly to distinctly scaly, scales appressed, mycelial rhizo-morphs present at base.

Spores (6.0–)6.5–7.2(–8.0) × (4.8–)5.2–7.0(–7.2) µm [X_m = 6.82 ± 0.8 × 5.8 ± 0.9 µm, Q = 1.1-1.25, Q_m = 1.18±0.04, n = 60 spores], yellowish-brown, globose to subglobose, oil granules present when viewed with KOH, apiculus short, echinulate ornamentation composed of low (up to 0.4µm) to high (up to 1.2µm) spines, apex obtuse, never reticulate. Basidia not observed. Capillitium hyphae 4.0–8.0 µm broad, interwoven,

Table 2. Genetic divergence matrix among four *Tulostoma squamosum* sequences based on nrDNA ITS sequences data.

GenBank accession no.	Geographic region	MN809136	KU519097	KT285883	KU519096
		India	France	Pakistan	Spain
MN809136	India	-			
KU519097	France	0.020	-		
KT285883	Pakistan	0.031	0.017	-	
KU519096	Spain	0.020	0.000	0.017	-

Image 1. *Tulostoma squamosum* (CUH AM696): A—field photograph of the basidiocarps | B—region of spore-sac attachment to the stem | C—detail of spore-sac showing tubular mouth | D—stalk surface | E—capillitium | F—spores | G—clamped hyphae (Scale: a = 20mm, b–c = 10mm, d = 20mm, e–f = 10µm, g = 20µm). © Arun Kumar Dutta.

hyaline, light yellow to brownish with KOH, septate, branched, thick-walled, lumen visible to lacunar. Gleba composed of more or less loosely arranged, 6.0–12.0 µm broad, interwoven, branched, septate hyphae, lumen distinctly visible, hyphal end clavate to subclavate or sometimes cylindrical, wall 0.4–0.8 µm thick. Stalk surface hyphae 6.0–9.0 µm broad, tightly arranged, hyaline, septate, oil granules present when viewed with KOH, thin-walled.

Habit and habitat: Solitary, scattered, in dead and decomposed leaf litter mixed soil among *Quercus* vegetation.

Known distribution: Europe, North America, Germany (Esqueda et al. 2004), Turkey (Sesli et al. 2000), Pakistan (Hussain et al. 2016), and now India (this study).

Specimen examined: AKD 3/2019 (CUH AM696), 08.vii.2019, India: West Bengal, Darjeeling District, beside Raj Bhavan, 27.051^{0}N & 88.262^{0}E, 2,105m elevation, coll. A.K. Dutta & S. Paloi.

Remarks: *Tulostoma squamosum* is morphologically characterized by the presence of a long, scaly stalk coloured reddish-brown, a spore sac (20–30 mm diam.) with a prominent tubular mouth, spores with echinulate ornamentation, membranous exoperidium and pale yellowish-brown endoperidium. Considering the membranous nature of the exoperidium and presence of tubular mouth, *Tulostoma squamosum* is categorized under the Sect. *Brumalia* Pouzar (Pouzar 1958).

Discussion

Tulostoma squamosum was originally described based on the collection made from Germany and later, Persoon (1801) designated the lectotype of the taxon based on his collection from Italy. The present Indian collection of *T. suqamosum*, however, matches well with that of the original description but, differs in having a larger basidiocarp with spore-sac measuring up to 30mm diam. and stalk 110–120 mm long; and larger spores (6.0–8.0 × 5.2–7.2 µm vs. 5.4–6.5 × 4.7–5.8 um).

The phylogenetic analysis based on nrITS region sequence data placed the present Indian collection along with the sequence of the same taxon collected from Spain, France, and Pakistan with strong statistical support values (98% BS, 1.00 PP; Fig. 1) suggesting all of them to be the morphotype of *Tulostoma squamosum*.

Among morphologically related taxa: *Tulostoma brumale* Pers. has an exoperidium coloured light brownish to cinereous brown outside and whitish inside, shorter stalk measuring 14–45 × 1.5–4 mm, coloured straw yellow to light brown with a peculiar sheen, and smaller spores with a mean of 5µm diam. with surface composed of small disperse verrucae (Wright 1987). *Tulostoma dumeticola* Long differs by having somewhat velvety exoperidium consisting of hyphae forming small tuberculate patches, circular mouth, and presence of anastomosed spines on the spore surface forming almost reticulate appearance (Wright 1987). *Tulostoma dennisii* has globose-depressed spore-sac, scaly exoperidium, small bulbous stalk base, and presence of mycosclereids (Wright 1987). The South American species, *T. bruchi* Speg. differs from *T. suqamosum* by its circular mouth, rugose stalk surface, and large papillate spores (Wright 1987).

Among phylogenetically close taxa (Fig. 1), *T. subsquamosum*, earlier reported to occur in India, has thin-scaly exoperidium, circular mouth, a socket that is separated from the stalk by a lacerated membrane, and presence of longer spines (4.6–6.1 µm diam.) as spore ornamentation (Wright 1987). *Tulostoma ahmadii*, described from Pakistan in the recent past (Hussain et al. 2016), differs by its light olive brown exoperidium, pinkish endoperidium, a socket that is composed of dentate and concentrically arranged membranes, presence of a much smaller stalk (30–40 mm long vs. 100–120 mm long), and somewhat larger spores with an average of 9.36 × 7.99 µm.

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NOTE

An account of a first record of the Common Goldeneye *Bucephala clangula* Linnaeus, 1758 (Aves: Anseriformes: Anatidae) in Bhutan

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Punatsang Chhu in Wangduephodrang (27.486^{0}N, 89.899^{0}E; 1,273m) is one of the largest rivers and an important zone in Bhutan for resident and migrant water birds. It is the expanse where diverse birds species are seen on a stretch between 27.462^{0}N–89.901^{0}E and 27.579^{0}N–89.867^{0}E (Tobgay 2017). Large numbers of winter migratory water birds in Bhutan have been found in this location (Spierenburg 2005). The Common Goldeneye *Bucephala clangula* was first sighted on 5 January 2019 along Punatsang Chhu 27.512^{0}N 89.887^{0}E at an elevation of 1,142m at 10.05h. On 8 January 2019, photographs of the bird were successfully taken at around 12.30h while it foraged along the sand extraction sites in the river. The duck was observed diving frequently under water foraging at the time of sighting. It was then photographed with the help of a DSLR canon 70D camera with a 70–300 mm until it flew away to the other side of the river.

The plumage, sloppy bill structure, triangular large head, and its prominent golden eyes apart from its other morphological features that identified the bird as the Common Goldeneye (female). Various field guides 'Birds of the Indian Subcontinent' (Grimmett et al. 2011) and 'Birds in Bhutan' (Spierenburg 2005) and experts' advice through Birds of Bhutan (social forum) were used for further verification. Dr. Sherub, the only ornithologist in Bhutan at Ugyen Wangchuk Institute for Conservation and Environmental Research (UWICER), Bumthang and international ornithologist Dr. Tim Inskipp also verified the bird record.

The Common Goldeneye is a medium-sized duck with a large head. The bill is fairly small and narrow with triangular shape, streamlined body and short tailed. Both sexes measure a length of 40–51 cm, weighing approximately 800g (Eadie et al. 1995; Johnsgard 2010) with a wingspan of 77–83 cm. Males are customarily white with white windows along the folded wing. Head blackish with an iridescent greenish glow (Johnsgard 2010), with a round white spot behind the bill. Females have a head that is completely dark chocolate brown that contrasts with its grey body (Johnsgard 2010). Bill is mostly blackish, with yellow at the tip. In flight it shows an extensive white on the inner half of the blackish wing. It is known as 'whistler' because of the whistling noise the wings make in flight (Eadie et al. 1995; Johnsgard 2010). Both sexes have golden-yellow eyes during

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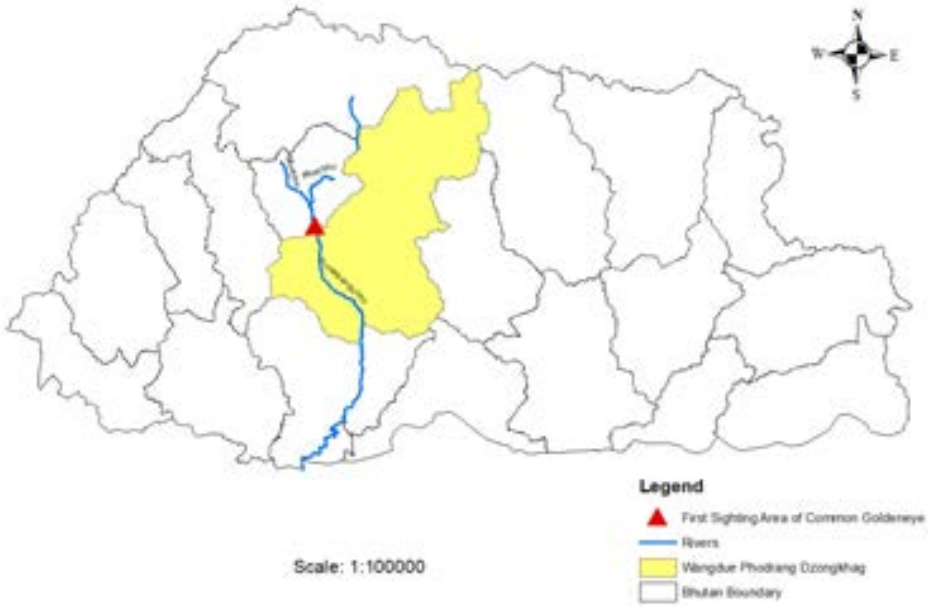

Figure 1. Location of first sighting and the distribution of the Common Goldeneye.

adulthoods but lack the golden eye in immature birds. Thus, it is named for its golden-yellow iris.

The Common Goldeneye is a confrontational and territorial duck (Eadie et al. 1995) competing for food and nest sites with other water birds. This species takes short-distance (Eadie et al. 1995; Kear 2005) flights but flies at higher altitudes when travelling over longer distances (Eadie et al. 1995), and breeds from April in solitary pairs (Del Hoyo et al. 1992; Eadie et al. 1995).

It is constrained to stay near the water close to the shore and less than 10m deep, showing a predilection for waters 4m deep (Scott & Rose 1996; Johnsgard 2010). They are diving birds that forage underwater preying on crustaceans, aquatic insects and plants and molluscs (Cottam 1939) and invertebrates (Erikson 1979). Their important food items consist of fish, invertebrate eggs, and aquatic plant materials (Eadie et al. 1995). They are fast fliers. When females are nearby, males recurrently display by elongating the head backward against their rear and then popping their head onward.

The suitable habitats include fresh water lakes, pools, rivers and deep marshes enclosed by coniferous forest (Del Hoyo et al. 1992; Johnsgard 2010).

This species ranges across the boreal forests of Scandinavia, eastern Europe, Russia, Mongolia, northern China, Canada, Alaska, and northern USA. Its wintering range is correspondingly broad, encompassing the coast of northern Europe including inland United Kingdom, scattered coastal and inland water bodies in southeastern Europe (Turkey) and central Asia, the coasts of eastern China, Korea, Japan and the Kamchatkha peninsula (Russia), the Pacific coast of Canada and the Alaskan coast and inland USA (Del Hoyo et al. 1992).

Image 1. The Common Goldeneye foraging near the sand extraction sites.

The IUCN Red List status of this bird is Least Concern owing to a stable population trend (BirdLife International 2019). Since it is the first record to Bhutan, the species is a vagrant and uncommon winter visitor to Bhutan. According to Tobgay (2017), 49 species of water birds along Punatsang Chhu basin were reported and more likely to have ascended with the sighting of the Whiskered Tern *Chlidonias hybridus* (18 August 2018), Grey Plover *Pluvialis squatarola* (18 November 2018) and the recent new record of the Common Goldeneye (5 January 2019).

Numerous birders in the country consider that

Punatsang Chhu, the expanse between Punakha and Wangduephodrang is a fundamental stopover domicile for many waterbirds and if any anthropogenic instability in the area will distress the migration of the bird species taking a route through Bhutan. Many birds have been threatened due to sand extraction and many development activities taking place currently.

With this confirmed record of the Common Goldeneye in Bhutan, the total number of avifauna recorded in Bhutan has reached 747, indicating a very high bird diversity for the size of the country.

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NOTE

First record of the hawkmoth *Theretra lycetus* (Cramer, 1775) (Sphingidae: Macroglossinae) from Bhutan

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The genus *Theretra* Hübner [1819] comprises small to medium sized, nocturnal hawkmoths belonging to subfamily Macroglossinae, tribe Macroglossini, subtribe Choerocampina (Kawahara et al. 2009). The adults of this genus feed mainly on nectar from flowers and are frequently attracted to light (Bell & Scott 1937). Of the 58 species reported from the Indian subcontinent, seven species have been recorded from Bhutan: *T. alecto* (Linnaeus, 1758), *T. clotho* (Drury, 1773), *T. nessus* (Drury, 1773), *T. oldenlandiae* (Fabricius, 1775), *T. silhetensis* (Walker, 1856), *T. tibetiana* Vaglia & Haxaire, 2010 (Irungbam & Irungbam 2019), and *T. sumatrensis* (Joicey & Kaye, 1917) (Lam Norbu, pers comm.). In the present paper we report the sighting of *Theretra lycetus* (Cramer, 1775) from Bajo Town, Wangdue Phodrang of central Bhutan.

Theretra lycetus was described by Pieter Cramer as *Sphinx lycetus* (Cramer, 1777), but the species was later transferred to the genus *Theretra* by Kirby (1892). It has been recorded from Nepal, southern & northeastern India, the Andamans, Sri Lanka, Myanmar, Thailand, Laos, Cambodia, Vietnam, and Malaysia (https://mol.org/species/map/Theretra_lycetus). The species is easily identified by the pale longitudinal double lines on the upperside of the abdomen becoming indistinct posteriorly, the darker pinkish-brown forewing upperside with strong postmedial lines and intervening pale bands, the hindwing upperside with a reddish medial band of variable width, and outer row of forebasitarsal spines with additional spines.

A single specimen of *Theretra lycetus* was photographed (Image 1) on the evening of 14 May 2019, at 18.10h, on the wall of the Wangdue Forest Range Office, Bajothang Town (27.4861 N, 89.8977 E; 1,216m) in Wangduephodrang District, Bhutan (Figure 1). The surrounding vegetation is dominated by an invasive small perennial shrub, *Lantana camara* L. (family Verbenaceae) and the wider area is cultivated with plants of family Vitaceae, which is one of the larval food plant families of *Theretra lycetus*. The specimen was subsequently identified by first author referring to Inoue et al. (1997) and then confirmed by Jean Haxaire, Muséum national d'Histoire naturelle, Paris,

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Figure 1. The present sighting locality in Wangduephodrang District, Bhutan.

Image 1. Adult *Theretra lycetus*.

France, through a social media communication (23 May 2019).

Previous studies on the Sphingidae fauna of the Indian subcontinent have reported the presence of this species, from the eastern Himalaya, southern India, Sri Lanka, and Myanmar (Bell & Scott 1937), and Mahakali, Nepal (Kishida 1998), but the studies conducted by Dudgeon (1898) in Sikkim and Bhutan did not record the species from Bhutan. Dierl (1975) reported 10 species of Sphingidae; Irungbam & Kitching (2014) reported 27 species of Sphingidae from Tsirang District; and Geilis & Wangdi (2017) reported 63 species of Sphingidae mainly from the studies conducted in eastern Bhutan, but none of these studies recorded *T. lycetus*. The latest updated checklist of the Sphingidae published by Irungbam & Irungbam (2019) includes 93 species from Bhutan but not *T. lycetus*. New records of Sphingidae, however, continue to accrue for the country. *Clanidopsis exusta* (Butler, 1875) and *Langia zenzeroides* (Moore, 1872) were reported for the first time from Bhutan only in 2019 (Jamtsho & Irungbam 2019; Irungbam & Norbu 2019). Thus, the present sighting of *T. lycetus* in Bajothang, Wangduephodrang of central Bhutan is significant and important and confirms the presence of the species in central part of the Himalaya.

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NOTE

Occurrence and association of the Scarce Lilacfork *Lethe dura gammiei* (Moore, [1892]) (Lepidoptera: Nymphalidae: Satyrinae) with Woolly-leaved Oak *Quercus lanata* Smith, 1819 (Fabaceae) forest in the Kumaon region of the Indian Himalaya

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The Scarce Lilacfork *Lethe dura* (Marshall, 1882) occurs as five subspecies. The subspecies *L.d. gammiei* (Moore, [1892]) has a distribution extending from Sikkim to Arunachal Pradesh including Bhutan and northeastern India with males being "not rare" while females being "very rare"; the nominate subspecies *L.d. dura* (Marshall, 1882) occurs in northwestern Yunnan, China (Huang 2003), Myanmar from Shan states up to Dawnas and is "very rare"; while the third subspecies *L.d. mansonia* (Fruhstorfer, 1911) occurs in Myanmar but only in Dawnas as "very rare" (van Gasse 2017) and in northern Vietnam; the fourth subspecies *moupiniensis* (Poujade, 1884) is known from western China; and the fifth subspecies *neoclides* Fruhstorfer, 1909 occurs in Taiwan (http://ftp.funet.fi/pub/sci/bio/life/insecta/lepidoptera/ditrysia/papilionoidea/nymphalidae/satyrinae/lethe/). Besides, there are records during May from Karen Hills and Tenasserim region of Myanmar (Marshall & de Nicéville 1882; Talbot 1947). In the Himalaya, the subspecies *L.d. gammiei* is found in Sikkim (Teesta Valley at ~1,500m and from Gangtok to Dikchu), Bhutan (Trashiyanstse; 1,500–3,000 m), Arunachal Pradesh, hilly forests of northeastern India (Khasi Hills), from 1,800–2,200 m with a flight period from April to November (Evans 1932; Wynter-Blyth 1957; Sbordoni et al. 2015; Kehimkar 2016; van Gasse 2017) (Fig. 1). A specimen of *L.d. gammiei* from Sikkim (1 male) was collected by O.C. Ollenbach on 04.vii.1920 which is kept at the National Forest Insect Collection (NFIC), Forest Research Institute, Dehradun (Fig. 2 a&b). There are records of *L.d. gammiei* from Kalimpong in West Bengal, western Sikkim, and Cherrapunjee in Meghalaya (https://www.ifoundbutterflies.org/). The larval food plant of the species is not yet known. D'Abrera (1985) (Figs. 3a,b), however, reports its occurrence from northwestern India, Sikkim, and Bhutan, but there are no site specific records of *L.d. gammiei* from either Garhwal or Kumaon regions of Uttarakhand in western Himalaya (Mackinnon & de Nicéville 1899; Hannyngton 1910; Singh & Sondhi 2016; Sondhi & Kunte 2018) or in Nepal where its congener, the Lilacfork *L. sura* Doubleday, 1850 is known to occur (Smith 1989, 2006). The species is currently

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Figure 1. The location of present records of the Scarce Lilacfork *Lethe dura gammiei* (Moore, [1892]) from Uttarakhand (Kumaon Himalaya) in relation to past records of the species in other areas across the Himalaya, in northeastern Indian hills, and in Myanmar.

Image 1. *Lethe dura gammiei* (Moore, [1892]) (male) from Sikkim (04.vii.1920) at NFIC at Forest Research Institute, Dehradun, Uttarakhand, India. Photo credit: Arun P. Singh.

protected and is listed in Schedule I, Part IV, of the Indian Wildlife Protection Act, 1972 (Anonymous 2006).

During the course of surveys in Uttarakhand, two males of *L.d. gammiei* were observed at Dharamghar forest area (Figs. 4a,b, 5; 29.868^{0}N & 80.007^{0}E; 1,989m; sub-type 12/C1a Ban Oak *Quercus leucotrichophora*

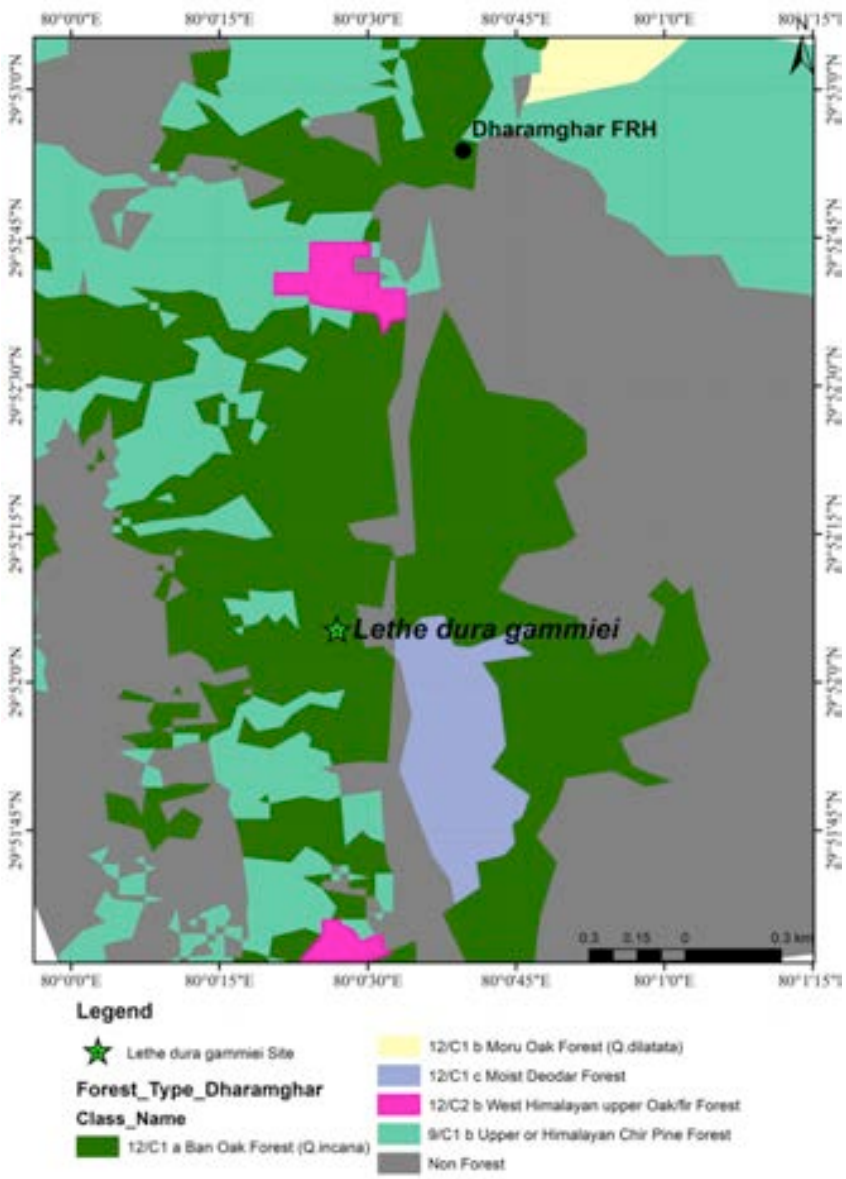

Figure 2. Location of the occurrence of the Scarce Lilacfork *Lethe dura gammiei* (Moore, [1892]) (Satyrinae) in Woolly-leaved Oak *Quercus lanata* Smith (Fabaceae) forest under sub-type 12/C1a Ban Oak Forest, in Dharamgarh in the Kumaon region of Uttarakhand.

Forest; 22°C; 76% RH at 09.25h on 16.ix.2019) in Pithoragarh District of Kumaon in Uttarakhand. The forest is dominated by Woolly-leaved Oak *Quercus lanata* Smith, 1819 (Riyanj) in pure patches (tree density ~1500 trees/ha; GBH varying from 30–131 cm; mean GBH of oak trees 67cm) and also with other associates like *Q. leucotrichophora*, *Rhododendron arboreum*, *Myrica esculenta*, and *Aesculus indica*. Three more individuals of *L.d. gammiei* were recorded near Shama Village (29.971^{0}N & 80.046^{0}E; 2,039m; sub-type:12/C1a Ban Oak Forest (Fig. 5); 26°C; 68% RH at 13.30h on 18.ix.2019) in Bageshwar District, Uttarakhand. The forest being dense and dominated by *Quercus lanata* intermixed with other associates like *Q. leucotrichophora*, *Alnus neplanesis, Rhododendron arboreum, Viburnum* sp. *Strobilanthus* sp., and *Colquhounia* sp.

Our observations suggest that in northeastern Kumaon, this species seems to be associated with *Quercus lanata* Smith (syn. *Q. lanuginosa* D.Don) which has overlapping distribution extending from Kumaon in Uttarakhand eastwards to Arunachal Pradesh, through Nepal, Sikkim, Bhutan, and extends into Myanmar; it grows gregariously in patches often associated with Ban Oak *Q. leucotrichophora* between 1,400–2,400 m in western Himalaya. *Q. lanata* has glabrous leaves when mature (Brandis 1911; Osmaston 1927; Polunin & Stainton 1989). The distribution of *Q. lanata* in the Kumaon region falls under the forest type 12/C1, lower

Image 2. *Lethe dura gammiei* (Moore, [1892]) (male) from Himalaya (photographs of the concerned species depicted on the species page in the book by D'Abrera (1985).

Image 3. *Lethe dura gammiei* (Moore, [1892]) (male) at Dharamgarh Forest (16.ix.2019; 1,989m), Pithoragarh District, Uttarakhand, India

western Himalayan temperate forests as per Champion & Seth's (1968) classification.

The current findings are the first site specific records of *L.d. gammiei* from the Kumaon region of the Himalaya and its unique association with Woolly-leaved Oak *Q. lanata*. These are also the first published records of the species from northwestern Himalaya confirming its occurrence in Uttarakhand.

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NOTE

Additions to the Odonata (Insecta) fauna of Asansol-Durgapur Industrial Area, West Bengal, India

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To examine the diversity, occurrence and distribution pattern of dragonflies and damselflies (Odonata) from the selected study sites of Asansol-Durgapur industrial area of Paschim Bardhaman District of West Bengal, India an investigation was conducted by A.K. Nayak from January 2012 to December 2015. A combination of direct search and opportunistic sighting methods was applied to record odonate species (38 dragonflies and 19 damselflies) from the varied region of the study area. On the basis of this study, the first work on the Odonata fauna of Asansol–Durgapur Industrial Area by Nayak & Roy (2016) was reported. The aim of the present study is to update the checklist of Odonata fauna of Asansol-Durgapur Industrial Area.

Study area

The present study conducted at all the same study points along with two new study sites Kalyaneshwari Temple, Asansol & Kumarmangalam Park, Durgapur situated at Asansol-Durgapur area (23.689–23.520 ^{0}N & 86.966–87.312 ^{0}E), an important industrial urban zone of Paschim Bardhaman District of West Bengal, India (Figure 1). The six odonates are found from six different study points. The details of 13 study points are given in Table 1.

Data collection: A combination of direct search technique (Sutherland 1996) and opportunistic sighting methods were applied during the present study (January 2016 to September 2019) to record odonate diversity and abundance. Observations were made by covering each study site twice a month involving different habitat types of odonates. During each sampling, efforts were made to enlist the encounter frequencies of different odonates from different sampling sites. The identification of odonates was done following Fraser (1933, 1934, 1936), Mitra (2006), Subramanian (2005, 2009, 2014), Nair (2011) and Babu et al. (2019). Nikon D5300 DSLR camera and Nikkor 70–300mm VR lens were used for photo documentation of the odonates.

A total of six different odonate species that involved both dragonflies (Anisoptera) and damselflies (Zygoptera) were recorded during the present study which was represented by six genera from four families. Among those reported families, one was represented by damselflies (Zygoptera), viz., Lestidae (one species and one genus). The rest of the three families were represented by dragonflies (Anisoptera), viz., Aeshnidae (one species and one genus), Gomphidae (two species and two genera), and Libellulidae (two species and two genera). The species *Gomphidia leonorae* Mitra, 1994 is reported for the second time from India in this paper and the range

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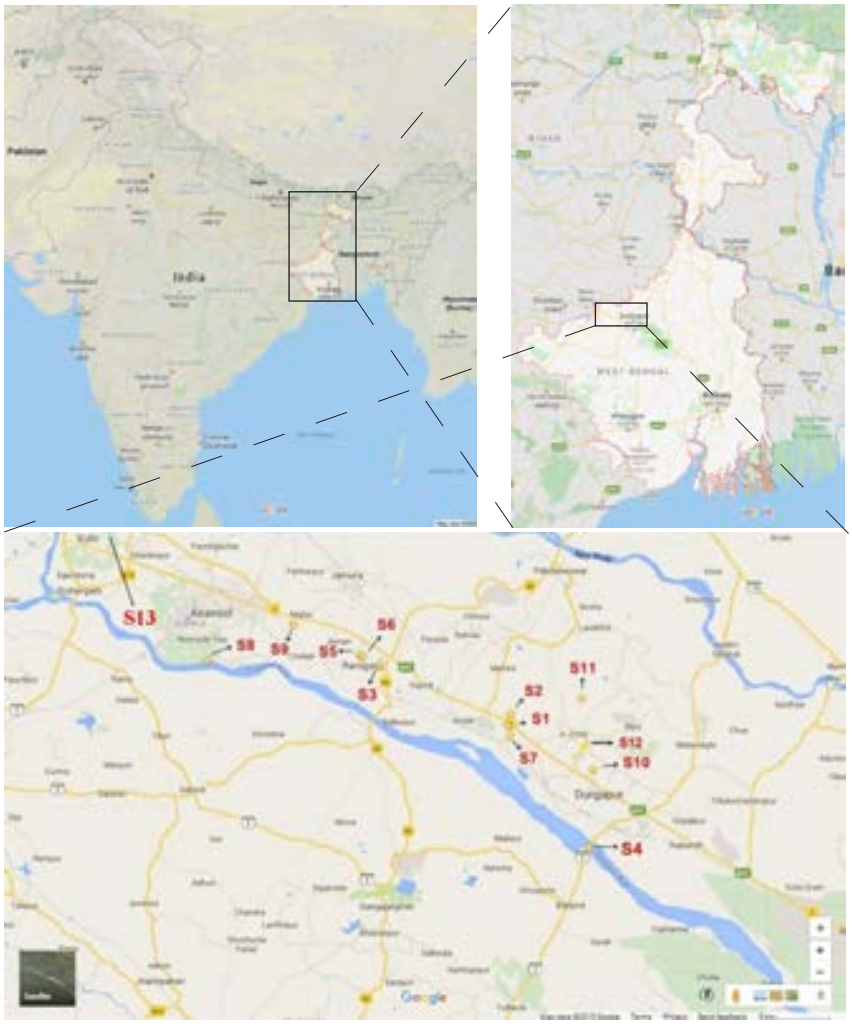

Figure 1. Study sites (S1–S13) under present investigation from Asansol-Durgapur area of Paschim Bardhaman District from West Bengal, India. Source: Google Maps.

extended from Susunia Hill, Bankura, West Bengal, India (23.395^{0}N, 86.987^{0}E) to Durgapur Barrage, Paschim Bardhaman, West Bengal, India (23.475^{0}N, 87.302^{0}E). A detailed account of findings on the six species found during the present study (January 2016–September 2019) is given below:

Suborder: Anisoptera

Family: Aeshnidae

1. *Anax ephippiger* (Burmeister, 1839)

31.viii.2019, Study Site – S2 (Image 1), Least Concern (Subramanian 2016)

Comment: Only one female species was found from the study area. The species was hovering over a paddy field and the flight was very agile. This species is not commonly seen in southern part of West Bengal.

Family: Gomphidae

2. *Gomphidia leonorae* (Mitra, 1994)

30.v.2017, Study Site – S4 (Image 2), Data Deficient (Sharma 2010)

Comment: Only one adult female of the species was known from Susunia Hill (Mitra et al. 1994). This time also a female species was found from a bushy river side area of Damodar at Durgapur Barrage, West Bengal.

3. *Macrogomphus montanus* (Selys, 1869)

26.vii.2014, Study Site – S1 (Image 3), Data Deficient (Subramanian 2010)

Comment: This species is not very common in southern Bengal and the author recorded it for the first time from the study area and another species from the same genus *Macrogomphus annulatus* was found in the same study site in 2014. This species was found under a shrub near the shade of a big tree.

Family: Libellulidae

4. *Orthetrum taeniolatum* (Schneider, 1845)

17.iv.2019, Study Site – S13 (Image 4), Least Concern (Mitra 2013)

Table 1. Brief description of the selected study sites including geo–coordinates and habitat types.

Location (study site)	Latitude (N)	Longitude (E)	Habitat type
S1 – Dubchururia Village	23.578°	87.228°	Remnants of dry deciduous forests with more than 20 large water bodies.
S2 – Andal Old Aerodrome	23.588°	87.230°	Open grassland and agricultural land with a slow flowing perennial stream.
S3 – Searsole Junior Basic School	23.630°	87.109°	Planted trees with four large water bodies surrounded by agriculture land.
S4 – Durgapur Barrage	23.475°	87.302°	Wetland dependent mixed vegetation with a perennial river.
S5 – Nimcha Village	23.638°	87.089°	Remnants of dry deciduous forests with eight large water bodies, interspaced with agricultural land.
S6 – Nimcha Coal Mine area	23.636°	87.093°	Mixed forest with a slow flowing perennial stream and open coal pits.
S7 – Gopalmath Rail colony	23.569°	87.229°	Open grassland and agricultural land with more than 10 large water bodies.
S8 – Nehru Park	23.634°	86.947°	Remnants of dry deciduous forests with a slow flowing perennial stream and a river.
S9 – Gunjan Ecological Park	23.664°	87.028°	Wetland dependent mixed vegetation with a large water body.
S10 – Ambuja Wetland	23.540°	87.306°	Wetland dependent mixed vegetation with a large water body.
S11 – Rana Pratap, A–Zone, Durgapur	23.601°	87.295°	Remnants of dry deciduous forests with a slow flowing perennial stream.
S12 – Mohan Kumarmangalam Park, B-Zone, Durgapur	23.564°	87.301°	Wetland dependent mixed vegetation with a large water body.
S13 – Kalyaneshwari Temple, Asansol	23.777°	86.829°	The study area situated beside the temple and the habitat is remnants of dry deciduous forests with a slow flowing perennial stream.

Comment: The species was found basking on a rock near a small stream. The day was too hot and the species was followed by various common species of the same genus. It is not very commonly seen in the study area.

5. *Trithemis aurora* (Burmeister, 1839)

19.iii.2017, Study Site – S9 (Image 5), Least Concern (Subramanian & Dow 2010)

Comment: The species was found in the dense area of Gunjan Ecological Park situated at Asansol. This species is common in West Bengal. The species likes shaded bushy areas.

Image 1. *Anax ephippiger* female, location - S2 (31.viii.2019).

Suborder: Zygoptera

Family: Lestidae

6. *Lestes viridulus* (Rambur, 1842)

22.xii.2017, Study Site – S12 (Image 6), Least Concern (Dow 2010)

Comment: The species is common and prefers to live under dense bushes and shaded area. The species was found from the new study site and this study site reported high Odonata diversity

Image 2. *Gomphidia leonorae* female, location - S4 (30.v.2017).

With the addition of these six new records, the total number of odonates stand at 63. Out of these six species, *Gomphidia leonorae* Mitra, 1994 is a very important finding and the author is further involved in searching for the male. Considering the previous study of odonates (recorded 57 species) from the same study area, the present species count is surely an underestimation. The author strongly believes that sustained and co-ordinated efforts are necessary for documenting the odonate diversity of the entire state. This is possible through networking between the amateurs and professional researchers. Furthermore, since odonates are considered as biological indicator species, it is necessary that long-term monitoring needs to be taken up for major water

Image 3. *Macrogomphus montanus* female, location - S1 (26.vii.2014).

Image 4. *Orthetrum taeniolatum* male, location - S13 (17.iv.2019).

Image 5. *Trithemis aurora* female, location - S9 (19.iii.2017).

bodies in the study sites as well as in the state. Future investigations covering more study areas will certainly enrich our knowledge and understanding of odonate diversity and ecology from this important industrial region.

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Image 6. *Lestes viridulus* female, location - S12 (22.xii.2017).

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NOTE

Gynochthodes cochinchinensis (DC.) Razafim. & B. Bremer (Morindeae: Rubioideae: Rubiaceae): an addition to the woody climbers of India

Pradeep Kumar Kamila [1], Prabhat Kumar Das [2], Madhusmita Mallia [3], Chinnamadasamy Kalidass [4], Jagayandatt Pati [5] & Pratap Chandra Panda [6]

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The family Rubiaceae, with 611 genera and approximately 13,143 species, is distributed in the tropical, subtropical, temperate, and arctic regions (Davis et al. 2009). The subfamily classification based on morphological characters divided Rubiaceae into four subfamilies, viz., Cinchonoideae, Ixoroideae, Antirheoideae, and Rubioideae (Robbrecht 1988), though recent molecular phylogenetic studies recognize three subfamilies such as: Cinchonoideae, Ixoroideae, and Rubioideae (Bremer 2009). One of the tribes of the subfamily Rubioideae is Morindeae (Bremer & Manen 2000; Bremer & Eriksson 2009), which is comprised of six genera namely, *Appunia* Hook.f., *Coelospermum* Blume, *Gynochthodes* Blume, *Morinda* L., *Pogonolobus* Muell., and *Siphonandrium* Schum. (Razafimandimbison et al. 2008).

Blume (1827) described the genus *Gynochthodes* by putting together the species having similar morphological features such as presence of 8–9 flowers per umbel on the inflorescence, flowers being villous inside the tube; 4–5 stamens, one style, bifid verrucous stigma, globose stipule, umbilicate drupe, 4-locular ovary and erect albuminous embryo. *Gynochthodes* can be segregated from other genera of the tribe Morindeae by having inflorescences that are never paniculate, small flowers (corolla tubes 0.7–5.5 mm long and corolla lobes 1.5–11.0 mm long) and partly exserted anthers (Razafimandimbison et al. 2009; Suratman 2018). Razafimandimbison et al. (2009) also discussed the circumscription of *Gynochthodes* in a wider sense to accommodate all lianescent species of *Morinda* with small flowers in order to make *Morinda* monophyletic based on molecular phylogeny. The majority of lianescent species of *Morinda* having multiple fruits have been transferred to *Gynochthodes* and necessary nomenclatural changes made (Razafimandimbison & Bremer 2011). According to Johansson (1987), the genus can be distinguished from *Morinda* by its lianescent habit, stipules and bracts with marginal hairs, terminal umbellate inflorescences, flowers with recurved calyx tubes, corollas with long hairs within the tubes and on the adaxial side of the lobes. As per the present

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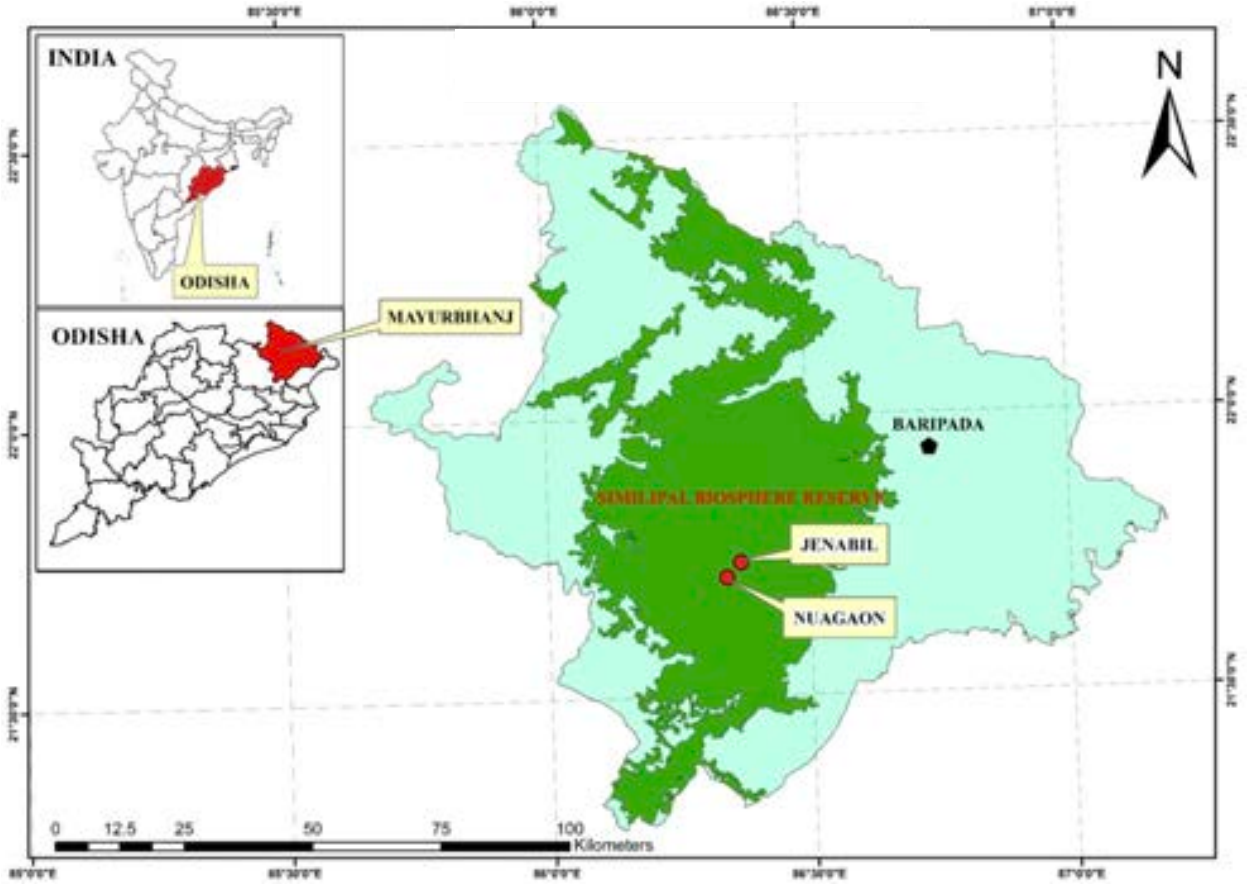

Figure 1. The distribution of *Gynochthodes cochinchinensis* in Similipal Biosphere Reserve, Odisha, India.

circumscription, the genus *Gynochthodes* is comprised of 93 species distributed mainly in tropical and subtropical Madagascar, Asia, and Australasia (Mabberley 2017).

During the population inventory of threatened plants of Odisha, we collected some interesting specimens of Rubiaceae from Nuagaon and Jenabil forest areas of Similipal Biosphere Reserve, Mayurbhanj District, Odisha, India at an altitude of 800–900 m. On critical examination of their morphological characters and consultation of relevant literature (Loureiro 1790; de Candolle 1830), we identified the species as *Gynochthodes cochinchinensis* (DC.) Razafim. & B. Bremer. Perusal of relevant literature revealed that this species has not yet been reported from within the geographical boundary of India and thus, turned out to be a new distribution record for India. A detailed botanical description along with notes on nomenclature, ecology, phenology, distribution, and color photographs of different plant parts are provided to facilitate easy identification of the species in the field. The herbarium specimens have been deposited in the Herbarium of Regional Plant Resource Centre (RPRC), Bhubaneswar, Odisha, India.

Gynochthodes cochinchinensis (DC.) Razafim. & B. Bremer, (Image 1)

Adansonia 33(2): 288 (2011). *Morinda cochinchinensis* DC., Prodr. 4: 449. 1830. *Morinda trichophylla* Merr., Philipp. J. Sci. 23: 267. 1923.

Lianas; branches woody and at base with persistent leafless stipules, when young densely ferruginous or yellow villosulous, terete to weakly quadrangular. Leaves opposite, mature leaf 12.0 × 6.5 cm, apex acuminate, base obtuse, veins 14 pairs, petiolate, petiole up to 1.0cm in length, young leaf 8 × 3 cm, apex acuminate to terete, base obtuse, 15 pairs of secondary veins, petiole 0.5mm, elliptic to ovate and sometimes oblanceolate, margin entire, adaxially sparsely strigose to strigillose, abaxially densely ferruginous or yellow hirtellous to villosulous with pubescence denser along veins. Stipules fused into the tube or spathe, 1cm in length, densely hispidulous to hispid on each side with two bristles, usually quickly deciduous. Inflorescence terminal, peduncles 8–15, umbellate, 4–5 cm long, densely ferruginous or yellow hirtellous, as a group subtended by two to several bracts of 1–3 mm long, two to several lobed. Each peduncle

Image 1. *Gynochthodes cochinchinensis* (Rubiaceae).
A—habit | B—stem with corky bark | C—leaf showing distinct secondary veins | D—tubular stipule | E—umbelliform inflorescence | F—close view of inflorescence | G—(i) calyx with hypanthium, (ii) flower, (iii) corolla tube with villous in nature, (iv) style with bifid stigma | H—young fruits | I—matured fruits | J—fruiting plants in wild | K—T.S. of a mature fruit | L—seeds. © P. K. Das & P. K. Kamila.

Table 1. Comparison of morphological characters of *Gynochthodes umbellata* and *Gynochthodes cochinchinensis*.

Morphological characters	*Gynochthodes umbellata*	*Gynochthodes cochinchinensis*
Branches	Glabrous, shiny and smooth, when young weakly angled often channelled, bluish-black to reddish-brown.	Scarbulous, rough and hard, when young densely ferruginous or yellow villosulous, quadrangular, dark brown to greyish-brown.
Leaves	Petiole 0.4–0.6 cm in length, glabrous, adaxially shiny and greenish, mid vein pale brown or brownish-black, abaxially matte, greenish.	Petiole 0.9–1.0 cm in length, pubescence, adaxially sparsely strigose to strigillose, mid vein light green to greenish-white, abaxially densely ferruginous or yellow hirtellous to villosulous.
Secondary veins	4–5 pairs.	14–15 pairs.
Stipules	Fused into a tube, 2–6 mm, scarious to membranous, puberulous, broadly rounded to truncate	Fused into the tube or spathe, 1cm, densely hispidulous to hispid, broadly triangular to truncate.
Peduncles	Peduncles 3–11, fasciculate, umbellate, or shortly racemiform, 4–11 mm, puberulous to glabrescent.	Peduncles 8–15, umbellate, 4–5 cm, densely ferruginous or yellow hirtellous.
Limb	Limb 0.2–0.8 mm in length, truncate to denticulate.	Limb 3–4 mm in length, unequal or reflexed.
Flower	Calyx glabrous, truncate to denticulate. Corolla campanulate, outside glabrous to puberulent; tube 1.2 mm, inside densely villous from middle to throat; lobes 4 or 5, narrowly oblong to ligulate, 2.2–3.0 mm, apically thickened and hooked.	Calyx with hypanthium portion densely strigose to strigillose. Corolla rotate to salver-shaped, lower surface pilosulous, upper part of petal hispidulous, inside densely villous throughout the tube onto lobes; tube 1.5 mm; lobes 4 to 5, narrowly oblong to lanceolate, 4.0–4.5 mm, apically thickened.

with one umbelliform inflorescence, sub-globose, 5–6 mm in diameter, 5–15 flowered; bracteoles linear, 0.2-–1.0 mm long. Limb sometimes unequal or reflexed, 3–4 mm in length, 2.2mm in diam., pilosulous. Flower with hypanthia partially fused, gamopetalous. Calyx with hypanthium, densely strigose to strigillose, sepals 4–5, narrowly triangular, 1–2 mm long, sometimes unequal on an individual flower. Corolla white, gamopetalous, rotate, 4–5 lobed, lower surface pilosulous, upper part of petal hispidulous, inside densely villous around the tube onto lobes; tube 1.5–2.0 mm; lobes 4 to 5, narrowly oblong to lanceolate, 4.0–4.5 mm, apically thickened and rostrate. Anthers four, oblong, 0.5mm in length, yellow in color, single margined in crimson red veined, basifixed, filament 1.0–1.5 mm in length, brown, stigma bilobed, attached directly to the ovary, linear, exerted, greenish in colour, papillose, 0.1mm in length, style 0.4mm, slightly pubescent. Ovary 2-celled with four locules, formed due to secondary false septa. Fruit drupaceous, subglobose or oblong or irregular, orange yellow to orange–red, 1–2 cm in diameter, peduncle elongating up to 4cm. Seeds 2 × 3 mm, slightly pubescent in nature, kidney shaped, orange to red in colour.

Flowering: May–June.

Fruiting: September–October.

Habitat: *Gynochthodes cochinchinensis* was found growing along forest roads close to perennial streams in the moist deciduous and semi-evergreen forest patches of Similipal Biosphere Reserve, Odisha, India at an altitude of about 900m (Figure 1).

Associated species: The species was observed to form association with *Lasiococca comberi* Haines, *Leea indica* (Burm.f.) Merr., *Uvaria hamiltonii* Hook.f. & Thoms., *Celastrus paniculatus* Wild., *Aphanamixis polystachya* (Wall.) R. Parker, *Styrax serrulatus* Roxb., *Polyalthia simiarum* (Buch.-Ham. ex Hook.f. & Thoms.) Benth. ex Hook.f. & Thoms., *Cipadessa baccifera* (Roth) Miq, *Combretum album* Pers. and *Xantolis tomentosa* (Roxb.) Raf.

Distribution: The species is native to southeastern China to Indo-china and reported to occur in Vietnam, and Thailand. In India, the species was not so far known to occur and the present report on wild occurrence of the species in Odisha extends the range of distribution of the species to India.

Specimens examined: 11038 (RPRC), 06.ix.2016, India, Odisha, Mayurbhanj District, Similipal Biosphere Reserve, Nuagaon, Jenabil, 21.71^{0}N & 86.34^{0}E, 887m; 21.73^{0}N & 86.36^{0}E, 900m, coll. P.K. Kamila & P.K. Das. (Image 2).

Common name: Lata Achhu (Odia), Bagackich (Vietnamese).

Use: Fruits are occasionally consumed by the tribals of Similipal Biosphere Reserve for its medicinal properties and assumed to reduce body weight. The birds and other frugivorous animals also feed on ripe fruits.

Taxonomic affinity: *Gynochthodes cochinchinensis* has morphological similarities with its closely related species *Gynochthodes umbellata* but both can be distinguished from each other by some distinct vegetative and floral characters. A comparative morphological differences between the two species is presented in Table 1.

Image 2. Herbarium specimen of *Gynochthodes cochinchinensis* housed in the herbarium of RPRC, Bhubaneswar, Odisha.

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NOTE

Record of *Oldenlandia hygrophila Bremek.* (Spermacoceae: Rubiaceae), a lesser known herb from Palghat Gap of Western Ghats, Kerala, India

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The genus *Oldenlandia* L. (1753) belonging to the tribe Spermacoceae Chamisso & Schlechtendal ex de Candolle (1830) of the family Rubiaceae is well distributed in the tropical and subtropical regions of the world (Govaerts et al. 2013). In India, the occurrence of the genus *Oldenlandia* is often debated with variable number of citations as 27 species (Hooker 1880) in the Flora of British India and 45 species (Gamble & Fischer 1923) in the Madras Presidency region alone. Estimates reveal the documentation of 14 species and one variety from the state of Kerala (Sasidharan 2011; Jose et al. 2015; Soumya et al. 2017).

Materials and Methods

During the exploratory studies on the floristic diversity of granitic hillocks in Walayar forest range of southern Western Ghats, the authors came across this taxon growing on the rocky outcrops near the dam site of Malampuzha in Palakkad District in July 2017. The specimens of the taxon were procured and herbarium was prepared using standard herbarium procedures. The plant specimens were characterised, measured and illustrated.

The specimen was identified to be *Oldenlandia hygrophila* Bremek. collected by Prof. Vasudevan Nair in 1972 cited from Malampuzha dam vicinity of Palakkad District (Bremekamp 1974) and confirmed the taxa from the type specimens deposited at Kew Herbarium (*O. hygrophila*: bar code no: K000031277). Regional herbaria (MH, KFRI and CALI) were consulted to check the presence of earlier collections of the taxon and found that N. Sasidharan had collected the taxa from Thrissur District in 1987 (Acc. No. KFRI 6945, collection No: N.S. 4635). Later, the taxa was reported from Muthanga region of Wayanad District in Kerala by Ratheesh Narayanan (RNMK 2228) in 2009. The taxon

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was not able to relocate from its type locality after its first collection by Prof. R. Vasudevan Nair in 1972. The acronyms for the herbaria follow the Index Herbariorum (Thiers 2018). The protologues of the allied taxa *Oldenlandia pumila* (L.f.) DC. and *Oldenlandia dineshii* Sojan & V. Suresh were also compared.

Oldenlandia hygrophila Bremek., Kew Bull. 29: 359. 1974; Narayanan, Fl. Stud. Wayanad Dist. 435. 2009. *Hedyotis hygrophila* (Bremek.) Bennet, Journ. Econ. Tax. Bot. 4: 592. 1983; Sasidharan et al., Bot. Stud. Med. Pl. Kerala 18. 1996; Sasidh. & Sivar., Fl. Pl. Thrissur For. 221. 1996; Dutta & Deb, Taxonomic Revision Hedyotis 140. 2004 (Figure 1 and Images 1,2).

Annual, erect, branched or unbranched herbs, 25–130 mm tall. Entire plant with sparsely distributed setiform cuticular protuberances. Stem quadrangular, minutely winged when old. Stipules connate, interpetiolar, 1.5–2

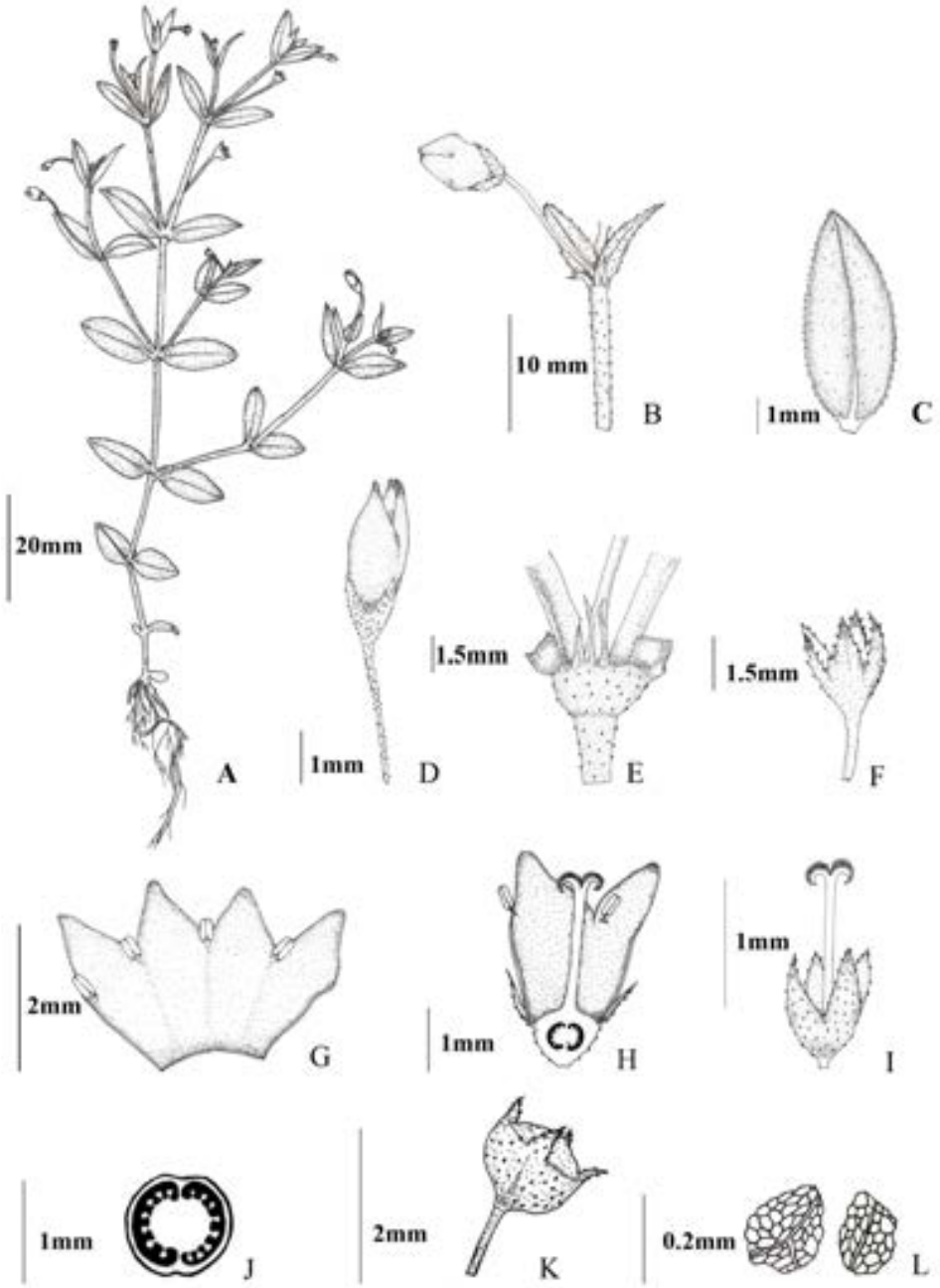

Figure 1. ***Oldenlandia hygrophila*** **Bremek.: A—habit | B—portion of a flowering twig | C—single leaf | D—single flower | E—part of node showing stipules | F—calyx | G—corolla tube opened showing stamens | H—L.S. of flower | I—gynoecium | J—C.S. of ovary | K—capsule | L—seeds. © V.J. Aswani & A. Rekha Vaudevan.**

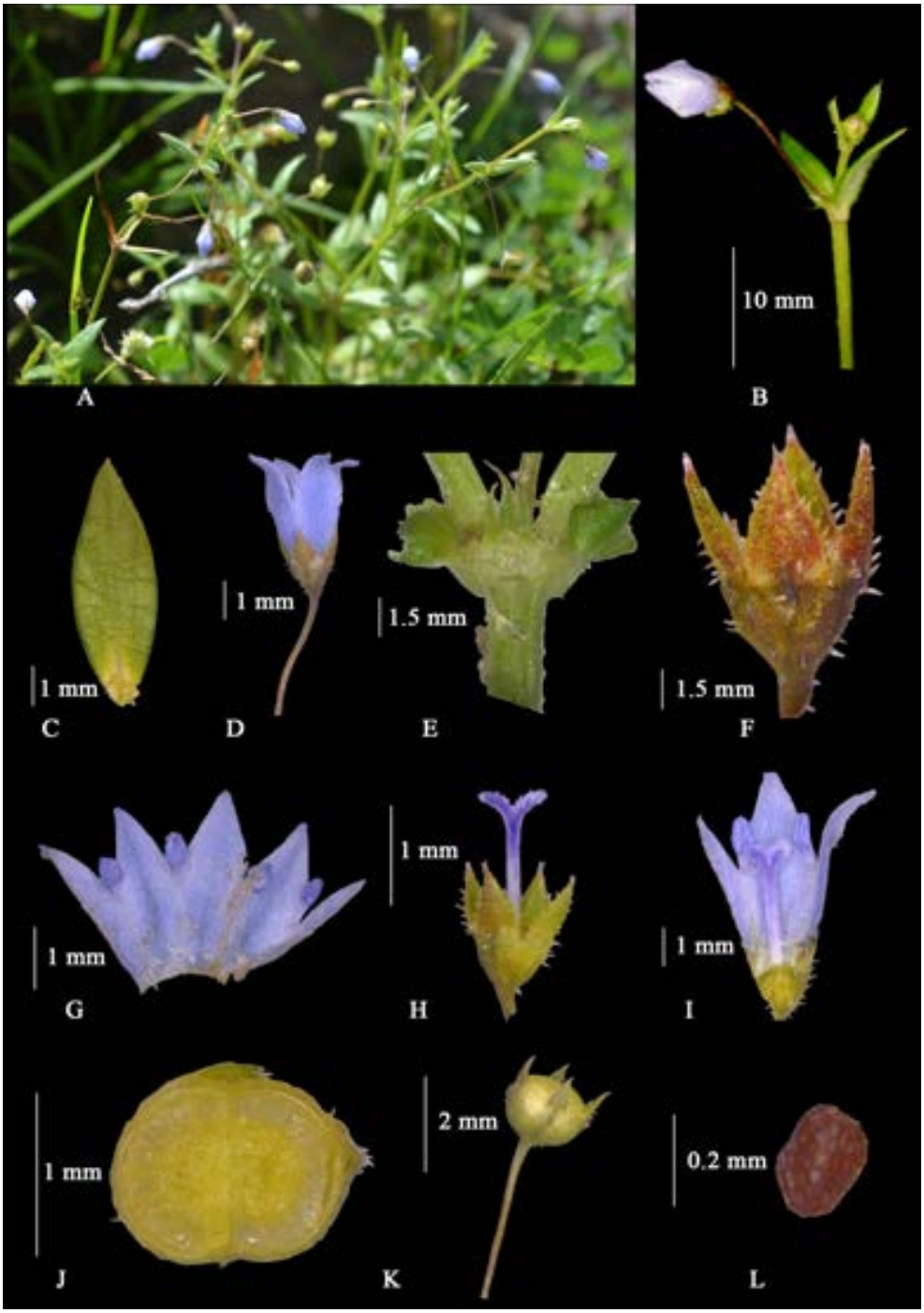

Image 1. ***Oldenlandia hygrophila*** **Bremek.: A—habit | B—portion of a flowering twig | C—single leaf | D—single flower | E—part of node showing stipules | F—calyx | G—corolla tube opened showing stamens | H—gynoecium | I—L.S. of flower | J—C.S. of ovary | K—capsule | L—seeds. © V.J. Aswani & M.K. Jabeena.**

mm long, 1–1.2 mm wide, with three bristles, middle one longer than the other two. Leaves sessile, 5–12 mm × 2–5 mm, linear lanceolate, 1–nerved, lamina base attenuate, margins recurved. Flowers axillary solitary, 3–3.5 mm long, corolla lobes not spreading when open. Pedicel slender, 6–10 mm, hypanthium ovoid and both laden with setiform cuticular protuberances. Calyx lobes 4, 1.5–2 mm × 0.8–1 mm, reaching one fourth of the corolla tube, margins entire, apex acute. Corolla blue, tube 2–2.2 mm long, lobe 1mm long, oblong, apex acute, glabrous outside and with small hyaline hairs inside at the base. Stamens 4, inserted, adnate to sinus of corolla

Table 1. Taxonomic delineation of *Oldenlandia hygrophila* from *O. dineshii* and *O. pumila*

Taxonomic Trait	*Oldenlandia hygrophila*	*O. dineshii*	*O. pumila*
Habit	Erect herb, branched and unbranched, 25–130 mm tall	Erect herb, dichotomously branched 50–200 mm tall	Branched prostrate or diffuse herbs
Stem	4–angled, minutely winged with setiform cuticular protuberances	4–angled, minutely winged, glabrous	Acutely angular, minutely dentate on ribs
Leaf	Linear-lanceolate, setiform cuticular protuberances present, 5–12 × 2–5 mm	Linear-lanceolate, sparsely scabrid, 10–20 × 5–8 mm	Elliptic-lanceolate, 7–18 x 1–6 mm
Leaf margin and leaf apex	Entire with regular setiform cuticular protuberances, recurved, apex acute, base attenuate	Apex acute, base attenuate	Scabrid above along margin and midrib below
Stipules	Bristles 3, 1.5–2 mm long, base broad up to 1–1.2 mm, middle one longer than other two	Bristles 2–3, 2–4 mm long, base broad up to 5mm.	Bristles 2–5, 2–3 mm long
Inflorescence	Axillary, solitary flowers alternating at nodes	Axillary, solitary or terminal 2–4 flowered cyme	Solitary or 2–flowered cyme
Flowers	3–3.5 mm long, blue	5–7 mm long, blue, campanulate	3–4 mm long, white
Pedicel	6–10 mm	4–6 mm long	10–15 mm long
Hypanthium	Ovoid with setiform cuticular protuberances	Ovoid, puberulous	Ovoid
Level of calyx lobes	One fourth of corolla tube	Much below the corolla tube	Below the level of corolla
Calyx	Margin entire with setiform cuticular protuberances, apex acute 1.5–2 × 0.8–1 mm long	Margin setulose, apex acute, 0.7–1 × 0.5–0.7 mm long	Margin dentate, lobes 4, rarely 5, ovate–lanceolate or triangular, apex acute, 0.5–0.6 mm long
Corolla	Lobes not spreading, tube 2–2.2 mm long, lobes 1mm long, oblong, acute at tip, glabrous outside and minute hyaline hairs at the base of corolla tube inside, apex slightly reflexed	Broadly campanulate, tube 2.5–4 mm long, lobes 2.5–3.5 mm long, minutely pubescent outside glabrous inside, apex reflexed	2mm long, tube 1.2–1.3 mm long, pubescent at throat; lobes 0.5–0.8 x 0.5–0.6 mm, ovate, acute, incurved at apex.
Stamens	Inserted, filaments 0.25mm long, glabrous	Inserted, filaments 0.7–1 mm long, hairy	Included, filaments 0.2–0.3 mm long
Anther	0.75mm	1–1.2 mm	3–4 mm long
Stigma	Bilobed, papilose	Bifid, hispid	Bilobed, papillose fleshy, tufted hairy
Capsule	Sub–globose 2×2 mm	Ovoid, 2.5–3 × 1.5–2.5 mm	Ellipsoid or oblong-ovoid
Seed	Many, angular, with minor grooves 0.2–0.3 x 0.2–0.3 mm	Many, angular 0.3–0.5 x 0.3–0.5 mm	Many, 0.7 x 0.1 mm, angular

lobes, introrse. Filaments 0.25mm long, glabrous. Anthers linear 0.75mm. Style 1.5mm long, glabrous. Stigma bilobed, 1mm, densely papillose. Ovary 1×1mm, 2–celled, many ovuled in axile placentation. Capsule sub-globose, 2×2 mm, loculicidally dehiscent from apex, with slightly raised crown above. Seeds numerous, trigonal, reticulate 0.3×0.2 mm.

Specimens examined: 361 (GVCH), 24 vii 2017, INDIA: Kerala: Palakkad District, Walayar range, Akathethara section, Koomachimala, 10.829°N, 76.676°E, 14m, coll. Aswani & Maya; 177855 (MH) 24.vii.2017, INDIA: Kerala: Palakkad District, Walayar range, Akathethara section, Koomachimala, 10.829°N, 76.676°E, 14m, coll. Aswani & Maya; 7004 (CALI) 24.vii.2017, INDIA: Kerala: Palakkad District, Walayar range, Akathethara section, Koomachimala, 10.829°N, 76.676°E, 14m, coll. Aswani & Maya.; 399 (GVCH) 12.viii.2017, INDIA: Kerala: Palakkad District, Walayar range, Akathethara section, Malampuzha (Koomachimala), 10.834°N, 76.680°E, 48m, coll. Aswani & Arabhi; 543 (GVCH) 15.ix.2017, INDIA: Kerala: Palakkad District, Walayar range, Akathethara section, Dhoni Hills, Neelippara, 10.8647°N, 76.6282°E, 282m, coll. Aswani & Rekha; 4173 (GVCH) 08.vii.2019, INDIA: Kerala: Palakkad District, Walayar range, Akathethara section, Malampuzha (Koomachimala), 10.829°N, 76.676°E, 15m, coll. Aswani & Jabeena (GVCH– Government Victoria College Herbarium).

Phenology: Flowering: June–August; Fruiting: July–September.

Distribution: India, Kerala: Palakkad, Wayanad, Thrissur districts.

Additional specimens examined: K000031277 (K), s.n. 1972, India, Kerala, Malampuzha near Palghat hardly 100m below, coll. R. Vasudevan Nair; 6945(KFRI), Collection no: N.S. 4635, 22.ix.1987, Peechi, Thrissur, coll. N. Sasidharan.

Ecology: This plant grows at an elevation of 14–252m in hydro geomorphic exposed rock surfaces along with *Drosera indica* L., *Utricularia lazulina* P.Taylor, *U. graminifolia* Vahl, *Indigofera uniflora* Buch. - Ham.

ex Roxb., *Desmodium triflorum* (L.) DC. and *Polygala persicariifolia* DC.

Threat status: This taxon could not be recollected from its earlier reported locations of forest areas in Thrissur and Wayanad districts of Kerala except from its type locality near Malampuzha Village very near to Malampuzha Dam region of Palakkad District, Kerala after its first collection in 1972. Exhaustive surveys across Palghat gap region covering the nearby forest ranges also could not locate the taxon. This gives us evidence of its narrow distributional range and that it can considered endemic to southern Western Ghats (restricted to Kerala). Till date, the taxon's existence was doubted due to lack of collection or further reports. This may be the reason that the taxon has not yet been evaluated as per the IUCN Red List 2019. Since the population size is very small, distributed in a narrow stretch of hydro-geomorphic habitats of less than 10km^2, the taxon can be assigned the status of Critically Endangered (CR) as per IUCN version 2019-3 (IUCN 2019).

Taxonomic delineation of *Oldenlandia hygrophila* from *O. dineshii* and *O. pumila*

Oldenlandia hygrophila is similar to *O. dineshii* in quadrangular stem and possession of blue flowers, but differs in the presence of setiform cuticular protuberance all over the plant, solitary axillary flowers smaller in size (2.5–3.0 x 1.5–2.0 mm), corolla lobes not spreading when open, sepals reaching one fourth the length of corolla tube, corolla tube glabrous outside, but with hyaline hairs at the base inside and glabrous staminal filaments. *O. hygrophila* differs from *O. pumila* in having erect nature of plant, linear-lanceolate leaves, solitary axillary blue flowers, shorter pedicels, calyx lobes reaching one-fourth the level of corolla lobes, corolla with minute hyaline hairs at the base of corolla tube inside and with sub–globose capsule. Comparison of taxonomic characters of *O. hygrophila* with *O. dineshii* and *O. pumila* is given in Table 1.

Image 2. Herbarium of *Oldenlandia hygrophila* Bremek.

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The State of Wildlife and Protected Areas in Maharashtra: News and Information from the Protected Area Update 1996-2015

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With about 7,000 stories and news reports, the Protected Area Update (PAU) constitutes a huge and valuable database. For nearly 25 years, and in over 140 issues, edited by Pankaj Sekhsaria, we have been getting brief access to happenings in different Indian states about aspects related to administration, legal aspects, management, conservation, people & research in wildlife, protected areas, and nature conservation.

The book in hand is about the state of Maharashtra. It is with news and information compiled and edited from PUCs published during 1996–2015. The earlier such compilation was in 2013 covering PAU news about northeastern India during 1996–2011. Congratulations to the editor and his team for the purpose addressed and output delivered through this well designed, neatly laid-out publication on Maharashtra, from the house of the famous Duleep Matthai Nature Conservation Trust.

The editorial notes and brief introduction about the protected area network in Maharashtra with a selected list of relevant references set a well-toned beginning, providing the minimum required details for global readership.

The Melghat Tiger Reserve (year 1973) of Maharashtra is one of the first nine tiger reserves of the country. The growth of tiger reserves to six numbers by 2014 and the concept of having interstate Pench Tiger Reserve holds the state in respect. Also, the state has a list of six other national parks, 38 wildlife sanctuaries, and two conservation reserves. Pages of the book offer chronological news from these areas, thoughtfully aided by an Index.

The Index-entries will be useful for lobbyists, conservationists, wildlife managers and governments which, before taking their own decision, seek examples in wildlife management practices or decisions from other parts of the country. Certain entries in the Index need rectifications or omits after page-matching. Although a book on Maharashtra, it does mention about a few other states like Andhra Pradesh, Assam, Chhattisgarh, Goa, Gujarat, Kerala, Madhya Pradesh, Rajasthan, Tamil Nadu, and Uttarakhand. A state like Odisha not appearing in this list indicates the future need to have better news-networking and translations of news from local other state languages for primary entry in PAUs. Some of the acronyms also need a place at page ii.

Out of three subject sections, the first section takes us year after year, through selected news and information from 34 areas covering wildlife sanctuaries, bird sanctuaries, conservation reserves, tiger reserves, national parks, eco-sensitive zones, and prime wetlands of importance in Maharashtra State. It also provides information about special research projects, like that

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on the Forest Owlets, the references to CAMPA, the Scheduled Tribes and Other Forest Dwellers (Recognition of Rights) Act (FRA 2006), developments about the Coastal Regulation Zone, Environment Protection Act, Biological Diversity Act, National Tiger Conservation Authority, decisions of the judiciary, decisions by the National Board for Wildlife, road expansion, staff deployment, garbage management, village relocation, mining, sacred groves, actions related to Great Indian Bustard, wild Water Buffalo, leopard problem, etc. It is a news treat.

Section-2 on 'Analysis and Perspectives' of five important aspects give access to research results and is thought provoking. 'Tribal Rights and Tiger Reserves' under the Wildlife (Protection) Act is still a topic of debate and challenge for wildlife manager of any Wildlife Protected Area.

Media contents in newspapers often constitute primary source of information as 'data' for verification, inclusion and analysis while writing an article or taking a managerial decision or process a research plan. Many a times, wildlife research have to start from such pieces of data obtained from the public direct or through local newspaper, which the modern and international scientific community may not like to bring under wildlife scientometrics (Singh 2015). On the other side, wrong reporting may also bring an end to facts hidden behind a report, as it had happened in 1930s for 'black tigers' (page-ii in: Singh 1999).

When I came to stay in Similipal Tiger Reserve for the next 16 years from 1987 after return from Government of India, it was after a gap of 80 months away from most of the fields in Odisha and with terrestrial wildlife. I resumed with newspaper items on man-wildlife interface, and developed my personal collection on bits of happenings from different parts of Odisha. Some items were understandably spiced-up by reporters, and needed to be accepted with editing; but there were the others that possessed 'something to accept about locations and the problem'. Around the same time, in an all-India scene, typed and mimeographed 'Environmental Abstracts', based on compilation of various news items were in circulation.

That was the click about location-wise importance of wildlife news. From 1990s PA Updates have presented professional compilation of news items focusing protected area locations. With Kalpavriksh-tag and support from Duleep Matthai Nature Conservation Trust, Pankaj Sekhsaria has obviously clipped off a lot and used selected items in the compiled-book on Maharashtra.

Pankaj Sekhsaria, well known for his research and books on the Andamans, with experience of more than two decades, has very thoughtfully added Section-3 to provide a complete issue of PAU (Vol. XXV, No. 4, August 2019, no.140). It gives ready reference to the original style and content of PAU issues.

It is interesting to search about the chronological news pertaining to any particular protected area in Maharashtra. Overall, the PA Update compilation in book format provides a good reference point and shows the need to have similar compilations for other states. Professionals as well as general readers, interested in or searching for happenings about wildlife conservation, will find the style and contents engaging. These could be the starting point for some research studies.

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