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COMMUNICATION

Presence of medium and large sized terrestrial mammals highlights the conservation potential of Patharia Hill Reserve in Bangladesh

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Abstract: Establishing and managing protected areas is a common approach for in situ conservation of wildlife and their habitats, but its effectiveness relies on the magnitude of anthropogenic pressures and their successful mitigation. Bangladesh is a densely populated country, and demand for land and natural resources is accelerated in and around the remaining forests. It is particularly of concern for an important transboundary hill forest, called the Patharia Hill Reserve in the northeastern Bangladesh, which appears to be the last resort for many important forest mammals. We conducted a camera-trap survey for assessing the occurrence of mammals in this tropical forest patch during January 2019 and July 2021. An effort of 2,805 trap-nights yielded 1,986 records of 22 medium and large-sized mammal species. We confirmed the presence of globally 'Vulnerable' Fishing Cat, Oriental Small-clawed Otter, Hog Badger, & Northern Pig-tailed Macaque and the globally 'Endangered' Phayre's Langur in this study. Our records include a number of species which are either the first record for the northeastern region or have been detected after several decades. In contrast, we could not detect several large carnivores which were recorded previously in the study site and in the Indian side of Patharia Hill Reserve. This study highlights the conservation value of this poorly known reserve forest, and presents a call for immediate action to maintain its function as a transboundary forest area.

Keywords: Activity pattern, Albino Hog Badger, mammals, semi evergreen forest, small carnivores, transboundary forest.

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Author contributions: MAR, AS, MSU, and MM conducted field survey with the help from MRKC, AH, and MAA. MAR and AS performed the analyses. MAA, AS and MAR prepared the draft of the manuscript. All authors contributed to editing the manuscript.

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INTRODUCTION

Protected areas have been mainstays of in situ conservation of wildlife and their habitats, and they have been generally effective in preventing large-scale land clearing (Bruner et al. 2001; Geldmann et al. 2019). However, deforestation is still observed in protected areas, combined with land conversion in buffer zones (Curran et al. 2004), which consequently, creates edge effects for mammal communities living therein (Kinnaird et al. 2003). Decline of mammalian species in protected areas due to hunting and other anthropogenic pressures has also been reported (Craigie et al. 2010; Harrison 2011). Such phenomena are particularly of concern where anthropogenic pressures from burgeoning human populations continue to increase around protected areas and remaining forests patches in tropical countries.

Bangladesh is considered a transitional zone for flora and fauna in southeastern Asia, being located in the Indo-Burma biodiversity hotspot. For the protection of its unique biodiversity, the Bangladesh government has established a network of protected areas comprising 20 national parks and 24 wildlife sanctuaries over decades (Bangladesh Forest Department 2022). However, Bangladesh is a densely populated country, and its population is still increasing (The World Bank 2022), thus demand for natural resources remains exceedingly high. In 1930, the country harboured four main forest areas, but currently only three remain covering only 12.8% of the entire land area: the Sundarbans in the southwest (mangrove), Chittagong and Chittagong Hill Tracts in the southeast, and greater Sylhet hilly forest areas in the north-east of Bangladesh (Reddy et al. 2016; Henry et al. 2021). Although the forest areas in Bangladesh continue to decline, yet the country is home to a total of 127 mammalian species, of which 60 species are known to occur exclusively in forests. Sadly, 11 species of mammals have been extirpated from the country over the last centuries, and around 40% of mammals are now threatened, and among them 19 are Critically Endangered (IUCN Bangladesh 2015).

The high deforestation rates in Chittagong Hill Tracts in the south-east, one of two main hilly forest areas of Bangladesh, has been reported in recent times (Reddy et al. 2016; Mamnun & Hossen 2021), suggesting that the remaining forest areas in the south-east and north-east becomes critically valuable for conservation of mammalian communities in the country. For instance, the northeast and southeast areas have been recognized as the last habitats for Asian Elephants *Elephas maximus* and other large mammals in Bangladesh (Islam et al. 2013; Ministry of Environment and Forests 2018). Despite of its importance of remaining forest areas in the northeast of the country, the status of mammalian communities in these areas is poorly known and scientific knowledge on them is scanty.

In the north-east, the past survey efforts for assessing mammalian species were limited to some protected areas, including the Lawachara National Park, Khadimnagar National Park and Rema-Kalenga Wildlife Sanctuary (Aziz 2011; Feeroz et al. 2011). It is reflected in the updated Red List of Bangladesh where one-third of the total national mammalian species have been categorised as 'Data Deficient' (IUCN Bangladesh, 2015). Besides the established protected areas in the north-east, one of the important and potential areas is Patheria Hill Reserve (PHR) forests are known to support diversity of wild animals. It is a transboundary hilly area bordered with India, and the importance of the area has been acknowledged in several studies, particularly for Asian Elephants, being carried out in the Indian sides (Talukdar et al. 2020a,b). These studies have identified PHR as one of the last habitats for many threatened animals including the Asian Elephant, Western Hoolock Gibbon *Hoolock hoolock*, Chinese Pangolin *Manis pentadactyla* and a range of other non-human primates (Talukdar & Choudhury 2017). Comparing with Indian side, the status of terrestrial mammals is poorly known Bangladesh, even though it is expected that the Bangladesh side of the PHR may harbour similar assemblage of mammalian fauna. As of today, only two studies focusing on medium- and large-sized terrestrial mammals were conducted in PHR: camera trap survey for two months with 300 camera-trap-nights (Rahman et al. 2021) and leech monitoring (Weiskopf et al. 2018).

Our knowledge of medium and large sized terrestrial mammals in the Bangladesh side of the PHR is largely lacking. To formulate conservation strategies to reverse the continued population decline of threatened mammals, field-based information on the occurrence of mammalian species is vital (Aziz et al. 2020). We therefore commissioned a survey using motion-trigger camera-traps to understand the current status of mammalian communities in the PHR of Bangladesh.

MATERIALS AND METHODS

Study area

The PHR is located within the Indo-Burma Biodiversity Hotspot and shared by Bangladesh and India across its border. Administratively, the PHR encompasses hilly

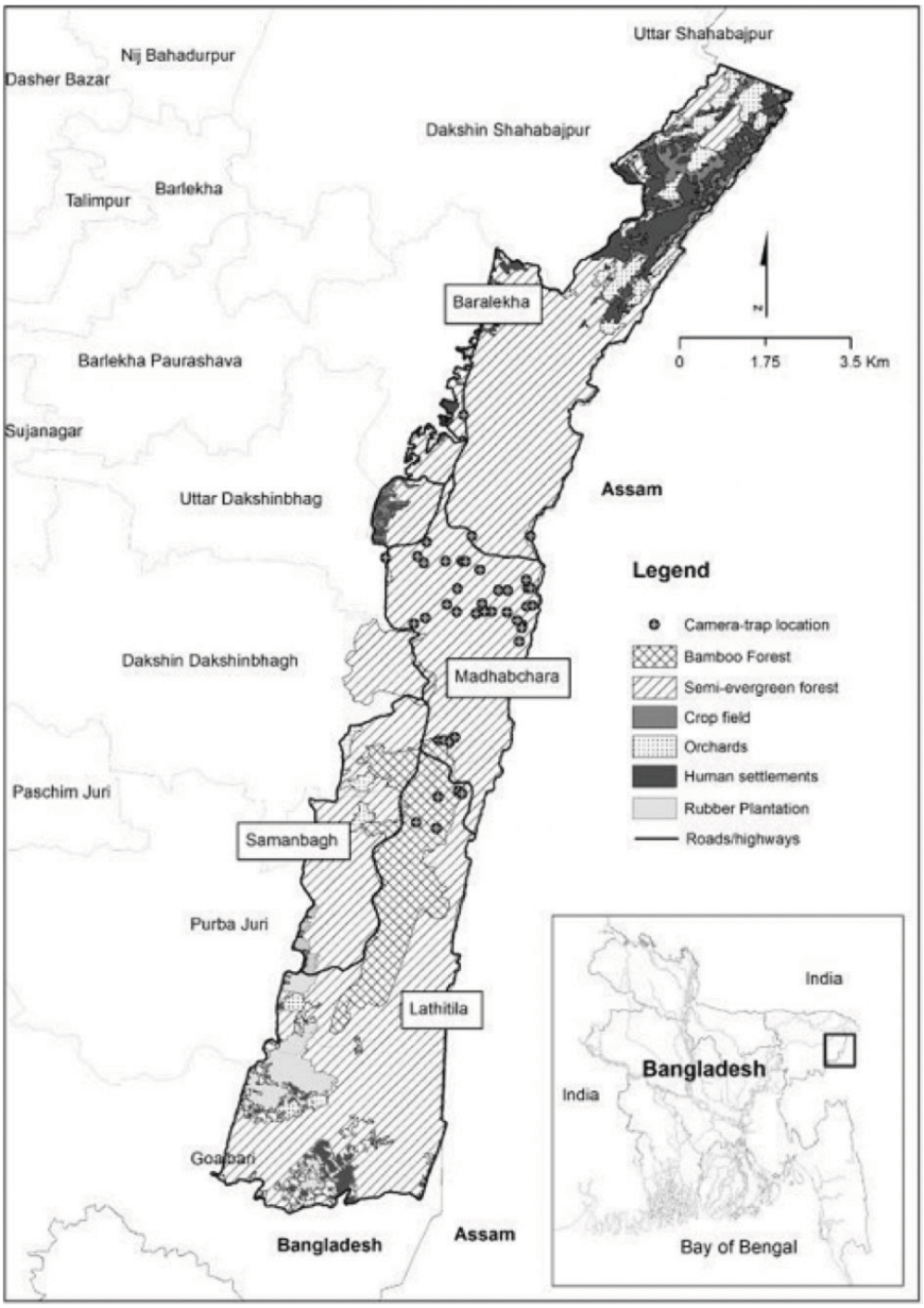

Figure 1. Map showing study sites and camera-trap locations in Patharia Hill Reserve of Bangladesh.

terrains with degraded forest landscapes across the Karimganj District of Assam in India and Moulvibazar District in Bangladesh. In Bangladesh, the Patharia forest was declared as a Reserve Forest in 1920 under the Forest Act, 1927, and managed by the Bangladesh Forest Department under four Forest Beats: Barolekha (1,303 ha), Madhabchhara (1,174 ha) and Samanbag (730 ha) under Barolekha Forest Range and Lathitila (5,510 ha) under Juri Forest Range (Figure 1) (Bangladesh Forest Department, 2021). Additionally, Madhabkunda Ecopark was declared covering an area of 265 ha demarcated from the Madhabchhara Forest Beat in 2001. The PHR comprises semi-evergreen vegetation that is largely degraded and remains as fragmented

forest patches. The effort of restoration is on-going by the Forest Department and local villagers under the benefit sharing agreement. The area also includes community-shared orchards, tea gardens, streams and valleys. The remaining patches of the reserve forests include dominant plant species such as *Tectona grandis*, *Albizia procera*, *Anthocephalus chinensis*, *Artocarpus chaplasha*, *Dillenia pentagyna*, *Gmelina arborea*, *Terminalia bellirica*, *Tetrameles nudiflora*, *Vitex peduncularis, Aporosa dioica*, *Dipterocarpus turbinatus, Garcinia pedunculata, Ilex godajam, Lophopetalum fimbriatum*, *Mangifera sylvatica*, and *Quercus gomeziana*.

The PHR is characterised by tropical monsoon with a hot and wet summer and a cool and usually dry winter. It receives high rainfall, with an average annual rainfall of 2,372 mm. The forest area enjoys two distinct periods: dry period from November to February (average rainfall of >35 mm/month) and tropical humid monsoon period with regular precipitation from May to September (average rainfall of <370 mm/month). Temperature varies from 20°C to 33°C, but in winter it sometimes decreases to 11°C. Average annual temperature is 24.8°C. Lowest temperature were recorded from October to February. Humidity varied from 63% to 89% with an average of 80.6% (Talukdar & Choudhury 2017).

Although the PHR constitutes an important forest landscape of the remaining forest patches in northeastern Bangladesh, currently the PHR is highly disturbed due to agricultural activities, cattle grazing and extraction of timber and non-timber forest products by communities living inside and around the area. The communities living this area traditionally grow betel leaves, betel nuts, pineapple, lemon, and mangoes within the forest lands for their livelihoods. In the Lathitila, southern part of the PHR, at least 300 households live in the southwestern parts. Alongside orchard gardening, forest villagers grow stream-fed rice and other cash crops in valleys and on hill slopes. As a result, most of the forest fringes and south-west regions are either modified or degraded, and devoid of any natural vegetation.

Camera-trap surveys

We conducted camera-trapping in two phases, from 12 January of 2019 to 6 April 2020, and from 23 February to 8 July 2021. In the first phase, a total of 10 infrared camera-traps (Bushnell Core DS 30 MP No Glow) were deployed at Barolekha and Madhabchara forest beats, and camera-traps were relocated to increase survey coverage and species detectability. In the second phase, we increased our camera-traps to 24 (additional 14 Browning Dark Ops Pro XD) for extending our survey coverage over the Lathitila and Samanbag forest beats, approximately 87 km^2 in total. In the second phase, camera-traps were deployed for 1,407 trap-nights for Madhabchara and 523 trap-nights for Samanbag and Lathitila forest beats. Unfortunately, a data storage card was stolen from one camera in the first phase while two camera-traps during the second phase. Two camera-traps were removed after two months of deployment from the field due to malfunction in the second phase.

Camera-trap locations were selected based on in-situ assessment of active animal trails including signs of feeding, resting and scats. All available habitat types including natural patches of forest vegetation, degraded forest and valleys, streams, and bamboo groves were considered for camera-trap placement. Inter-distance between camera-traps ranged from 300 m to 500 m, with an average distance of 350 m.

We mounted each camera-trap approximately 2–5m above the ground on a tree, targeting medium- and small-sized mammals within camera exposure range. Undergrowth vegetation and twigs were trimmed from camera exposure range to allow uninterrupted capture of good quality images of the moving animal. No camera-trap stations were lured. Each camera-trap was set to operate for 24 hours with motion sensor mode for capturing three consecutive still images and a video afterwards for 10 seconds. Date and time were set to stamp on each recorded image for ease of keeping data in order.

Species identification

Small mammals (the body weight <1kg), mostly rodents, were excluded from the analysis except for porcupines. The occurrence of Large-toothed Ferret Badger *Melogale personata* has been documented in the region, however, the occurrence of Small-toothed Ferret Badger *Melogale moschata* was also reported in the Indian side of this region. Considering the distance from the national border in the area, we could not assume the ferret badger recorded in the survey is *Melogale personata* without tooth measurement. Here, we cautiously assigned all images of Ferret badger to *Melogale* spp.

Data analysis

We defined a camera trap record as a record if it occurred at least 30 minutes after a photograph of the same species at a given station. The total sampling effort is expressed as the total number of camera-trap-nights,

one camera-trap-night being defined as a continuous 24 hr period of normal camera operation. Encounter rates were calculated as the number of records per 100 camera-trap-nights.

Activity patterns of species were examined using the time stamped on camera-trap images. The time stamp of camera traps provided the time and day when the photograph of the species was taken. Activity pattern were analyzed following Ridout & Linkie (2009). All analysis was conducted using the package "Overlap" in version 0.2.6 in R (Meredith & Ridout 2016).

RESULTS

Recorded species

Our survey efforts comprising 2,805 camera-trap-nights over two seasons produced 1,986 records of confidently identified species (Table 1). Twenty-two species representing four orders were photographed including one 'Endangered' species, namely, Phayre's Leaf Monkey. The three most commonly detected species across two surveys were the Crab-eating Mongoose, Common Palm Civet, and Wild Boar. Golden Jackal, Fishing Cat, and Small Indian Mongoose were detected only in the 2019/2020 survey while Asian Golden Cat, Rhesus Macaque, and Phayre's Leaf Monkey were recorded only in the 2020/2021 survey. The Asian Golden cat and Fishing Cat were detected only once during the study period. Overall, the order Carnivora accounted for 68% of all mammalian species, representing four species from each of the family Felidae, Mustelidae, & Viverridae, two species from Herpestidae, and one species from Canidae. Primates were represented by three species of macaques and one species of langur. Comparing to other two surveys in the same area, we have 14 species as new records, in particular for small carnivores. On the other hand, we have not detected Asian elephant and Capped langur in our camera trap survey although we found elephant footprints in the area. Comparing from interview surveys in the India side, the most striking results is that we have not detected large carnivores such as Leopards, Clouded Leopards, Dhole, and Black Bear throughout the two phases (Table 2).

Activity patterns

Activity patterns of species with >50 records are shown in Figure 2. Ferret Badger exhibited strong nocturnal patterns while Leopard Cat, Oriental Small-clawed Otter, Large Indian Civet, and Wild Boar showed its activity peaks both in the night time and around dawn and dusk. Crab-eating Mongoose exhibited diurnal patterns. Muntjac showed the peak of activity in the morning and increased again around dusk.

DISCUSSION

We confirmed the presence of 22 medium/ large-sized mammalian species, accounting for approximately 30% of forest-dwelling mammalian species in Bangladesh (IUCN Bangladesh 2015). Importantly, the list contains the globally Endangered Phayre's Langur, and four globally 'Vulnerable' mammalian species comprising the Fishing cat, Oriental Small-clawed Otter, Hog Badger, and Northern Pig-tailed Macaque. Of note, 11 species of mammals detected in this study have been listed in the threatened category of the International Union for Conservation of Nature (IUCN Bangladesh 2015). Occurrence of such a high assemblage of threatened species within a relatively small patch of transboundary forest highlights the conservation value of this poorly known reserve forest in northeast Bangladesh.

Carnivores

Our data confirms the occurrence of 15 carnivore species in PHR. We could not detect any large carnivores during our survey as well as the previous camera trap study conducted in the site (Rahman et al. 2021), although there are records of bear and leopard from the region in the past (Pocock 1939; Sarker & Sarker 1984; IUCN Bangladesh 2015; Talukdar & Choudhury 2017). Even our camera trap setting had the bias towards the distance from water sources for fishing cat survey, we still have not detected any sign and footprint of large cats and bears during our survey in two successive dry seasons and one wet season. In addition, three camera trap stations were set in the area where local sightings of leopard were occurred five years ago of the survey. Non-detection of large carnivore in this survey is unlikely to be explained by only biases in camera trap stations.

Compared with large carnivores, a number of small carnivores detected in this study are particularly notable because of their rarity and on site record. One of such species is the Ferret Badger. Although they could belong to either Large-toothed or Small-toothed Ferret Badgers, this is the first record of the Ferret Badger in the wild in Bangladesh. A reasonable encounter rate of this species allows us to explain the activity pattern of Ferret Badger in the study site (Figure 2). It was exclusively nocturnal, which is consistent with the pattern in other area such

Table 1. Records of medium- and large-sized terrestrial mammals in Patharia Hill Reserve during the 2019–2020 and the 2020–2021 surveys.

Order	Family	Scientific name	English name	The 2019–2020 survey			The 2020–2021 survey			Species status	
				No. of independent records	Encounter rate	No. of camera trap stations detected	No. of independent records	Encounter rate	No. of camera trap stations detected	IUCN Red List	National status
Carnivora	Canidae	*Canis aureus*	Golden Jackal	3	0.43	1	0	0	0	LC	LC
	Felidae	*Prionailurus viverrinus*	Fishing Cat	1	0.15	1	0	0	0	VU	EN
		Felis chaus	Jungle Cat	1	0.15	1	2	0.10	2	LC	NT
		Catopuma temminckii	Asian Golden Cat	0	0	0	1	0.05	1	NT	VU
		Prionailurus bengalensis	Leopard Cat	39	5.64	9	39	1.85	17	LC	NT
	Herpestidae	*Herpestes urva*	Crab-eating Mongoose	238	34.39	11	551	26.08	25	LC	NT
		Herpestes auropunctatus	Small Indian Mongoose	5	0.72	1	0	0	0	LC	LC
	Mustelidae	*Melogale* spp.	Ferret Badger	33	4.77	2	18	0.85	7	LC	Not listed
		Arctonyx collaris	Hog Badger	4	0.58	2	11	0.52	7	VU	VU
		Aonyx cinerea	Oriental Small-clawed Otter	37	5.35	8	77	3.64	12	VU	EN
		Martes flavigula	Yellow-throated Marten	3	0.43	2	5	0.24	5	LC	VU
	Viverridae	*Paradoxurus hermaphroditus*	Common Palm Civet	157	22.69	9	192	9.09	15	LC	LC
		Viverra zibetha	Large Indian Civet	51	7.37	9	15	0.71	7	LC	NT
		Paguma larvata	Masked Palm Civet	1	0.15	1	1	0.05	1	LC	VU
		Viverricula indica	Small Indian Civet	34	4.91	3	2	0.10	2	LC	NT
Cetartiodactyla	Cervidae	*Muntiacus vaginalis*	Northern Red Muntjac	59	8.53	7	90	4.26	21	LC	EN
	Suidae	*Sus scrofa*	Wild Boar	43	6.21	9	143	6.77	13	LC	LC
Primates	Cercopithecidae	*Macaca assamensis*	Assamese Macaque	5	0.72	2	38	1.80	15	NT	EN
		Macaca leonina	Northern Pig-tailed Macaque	4	0.58	2	21	1.00	8	VU	EN
		Macaca mulatta	Rhesus Macaque	0	0	0	15	0.71	9	LC	VU
		Trachypithecus phayrei	Phayre's Leaf Monkey	0	0	0	3	0.14	2	EN	CR
Rodentia	Hystricidae	*Hystrix brachyura*	Malayan Porcupine	7	1.01	3	37	1.75	9	LC	LC

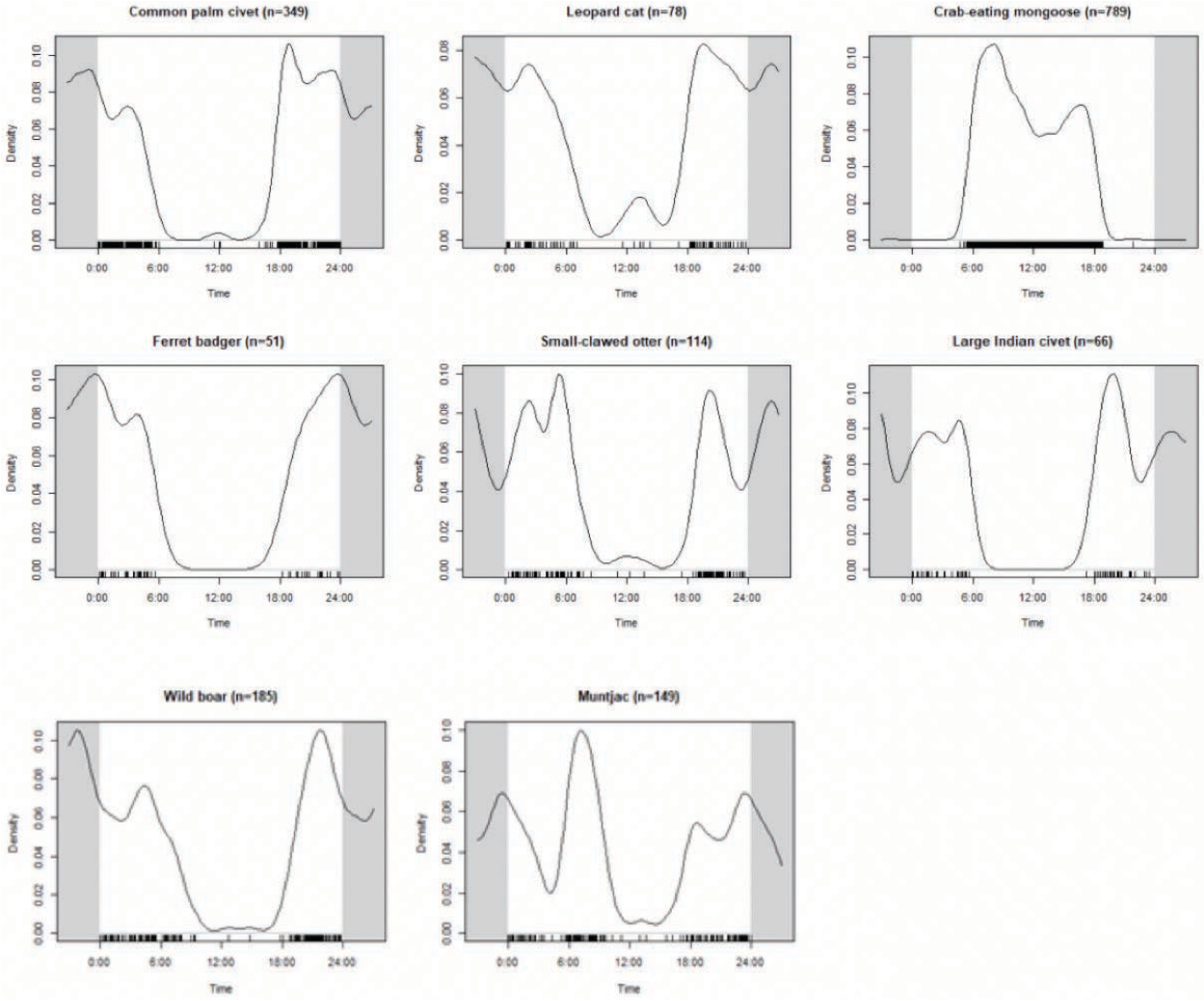

Figure 2. Activity patterns of eight mammal species detected >50 times during the 2019–2020 and 2020–2021 surveys in Patharia Hill Reserve, Bangladesh.

as Taiwan (Chen et al. 2009), China (Wang & Fuller 2003), and Cambodia (Suzuki et al. 2017). Interestingly, no Ferret Badger species was listed and evaluated in the updated Red List of Bangladesh (IUCN Bangladesh 2015), although there was a single record of Large-toothed Ferret Badger in 2008 from a small private zoo in the northeast Bangladesh (Islam & Belant 2008). Given the records of both badger species in areas of northeast India (Long & Killingley 1983; Choudhury 2013; Menon 2014), close to our study sites, both of the Ferret Badger species might occur in the PHR of Bangladesh.

In addition to Ferret Badger, three species of Mustelidae were detected. During our survey, the Oriental Small-clawed Otters was frequently photographed in streambed for both years. Our spatial configuration of the camera traps could increase the detectability of the otters along with streams as well as season, but the presence of the species warrants further investigation of the potential conservation significance of this area for this species. A recent study reports its sign from the Lathitila forest, adjacent to our study site (Akash et al. 2022a) and such hilly streams provide important habitat in India (Perinchery et al. 2011). It would be worth to explore the conservation importance of the PHR addition to the Sundarbans mangrove forest (Aziz 2018), considering the illegal demand for the species (Gomez et al. 2017; Uddin et al. 2022). Blandford (1888) reported the presence of Hog Badger in Sylhet, but the subsequent records of this species in Bangladesh were reported only from several locations in southeast Bangladesh (Feeroz et al. 2012), and uncertain records in Chittagong Hill Tracts (Khan 1984). Recently, it was reported from Sylhet region (Akash et al. 2022b). Interestingly, we found an albino individual captured

Table 2. Comparison of the records of small- and medium-sized mammals in Patharia Hill Reserve across four different surveys.

Order	Family	Scientific name	English name	Bangladesh side			Indian side
				This survey (Camera trap)	Rahman et al. (2021) (Camera trap)	Weiskopf et al. (2017) (Leech monitoring)	Talukdar & Chaudhury (2017) *2 (Interview and literature)
Carnivora	Canidae	*Canis aureus*	Golden Jackal	✔			✔
		Cuon alpinus	Dhole				✔
	Felidae	*Prionailurus viverrinus*	Fishing Cat	✔			✔
		Felis chaus	Jungle Cat	✔			✔
		Catopuma temminckii	Golden Cat	✔			✔
		Prionailurus bengalensis	Leopard Cat	✔	✔		✔
		Neofelis nebulosa	Clouded Leopard				✔
		Panthera pardus	Leopard				✔
	Herpestidae	*Herpestes urva*	Crab-eating Mongoose	✔			✔
		Herpestes auropunctatus	Small Indian Mongoose	✔			
	Mustelidae	*Melogale* sp.	Ferret Badger	✔	✔		✔
		Arctonyx collaris	Hog Badger	✔			✔
		Aonyx cinerea	Oriental Small-clawed Otter	✔			✔
		Lutrogale perspicillata	Smooth-coated Otter				✔
		Martes flavigula	Yellow-throated Marten	✔			
	Viverridae	*Paradoxurus hermaphroditus*	Common Palm Civet	✔	✔		✔
		Viverra zibetha	Large Indian Civet	✔			✔
		Paguma larvata	Masked Palm Civet	✔	✔		✔
		Viverricula indica	Small Indian civet	✔			✔
		Arctictis binturong	Binturong				✔
	Ursidae	*Ursus thibetanus*	Asiatic Black Bear				✔
Cetartiodactyla	Cervidae	*Muntiacus vaginalis*	Northern Red Muntjac	✔	✔	✔*1	✔
	Suidae	*Sus scrofa*	Wild Boar	✔	✔	✔	✔
Proboscidea	Elephantidae	*Elephas maximus*	Asian Elephant		✔		✔
Primates	Cercopithecidae	*Macaca* sp.	Macaque			✔	
		Macaca assamensis	Assamese Macaque	✔			✔
		Macaca leonina	Northern Pig-tailed Macaque	✔	✔		✔
		Macaca mulatta	Rhesus Macaque	✔			✔
		Macaca arctoides	Stump-tailed Macaque				✔
		Trachypithecus phayrei	Phayre's Leaf Monkey	✔			✔
		Trachypithecus pileatus	Capped Langur		✔		✔
	Lorisidae	*Nycticebus bengalensis*	Bengal Slow Loris				✔
	Hylobatidae	*Hoolock hoolock*	Western Hoolock Gibbon				✔
Rodentia	Hystricidae	*Hystrix brachyura*	Malayan Porcupine	✔	✔		✔
		Atherurus macrourus	Asiatic Bush-tailed Porcupine				✔
Lagomorpha	Leporidae	*Lepus nigricollis*	Indian Hare				✔
Pholidota	Manidae	*Manis pentadactyla*	Chinese Pangolin				✔

*1—Originally, the records of *Muntiacus muntjac* was reported, but it changed to *Muntiacus vaginalis* following the current phylogeography study on red muntjacs (Martins et al. 2017). *2—Following species were excluded from the list due to sceptical records based on known distribution: *Herpetes javanicus, Lutra lutra, Muntiacus muntjak,* and *Capricornis rubidus.*

in camera-traps for the first time in Bangladesh (Image 1J). The Yellow-throated Marten was detected during both seasons with only eight independent records. A previous camera trap study detected this species from another forest in the northeast region (Aziz 2011) but it remained undetected in the PHR (Rahman et al. 2021).

Four species of cats (Felidae) were detected during this survey. The globally and nationally threatened Fishing Cat was detected only once during the 2019–2020 dry season survey near the Indian border. Although camera traps were initially set for detecting Fishing Cats in the PHR forests, only a single record from two season surveys indicates that the cat could be relatively in low density in the PHR. The Asian Golden Cat was also photographed only one time. This may not accurately reflect their status due to our sampling bias towards water sources, but still plausible that the population of this secretive cat could be inherently low, considering the fact that the previous camera traps in this area did not detect this species (Rahman et al. 2021), even this species is likely to be found in various forests (Mittermeier & Wilson 2009; Zaw et al. 2014; Dhendup 2016). The Jungle Cat was recorded in a single camera-trap station placed in an area having degraded forests dominated by agricultural land. The Leopard Cat was relatively common in this area, and a Leopard Cat with her kitten was the photographed in the first week of May (Image 1E). Whilst we detected four cat species, only leopard cat was detected in the past by Rahman et al. (2021) from PHR, highlighting the importance of investing an increased number of trap-nights for recording elusive cats. Of four felid species, only Leopard Cat has reasonable number of records for the activity pattern, demonstrating that the cat is nocturnal and crepscular tendency, consistence with Grassman (2000), Lynam et al. (2013), Mukherjee et al. (2019).

Two species of Herpestidae were recorded in this survey. The Crab-eating Mongoose was the most frequently photographed species during this survey, and our biases in setting camera trap stations close to water resources streams is likely to have resulted in high encounter rate. This species has been found in this region, but currently no further ecological information is available beyond the presence data (Feeroz 2015a; Hasan et al. 2018). With a number of hilly streams, this area could be a source of the knowledge of this species such as investigating habitat requirements and population. The activity pattern of this species exhibits strongly diurnal, consistent with previous studies (Chen et al. 2009). Another mongoose species, the Small Indian Mongoose, was also photographed in daytime, but their distribution was restricted to the forest edges. The number of this species recorded was not enough to look at activity pattern.

Other medium- and large-sized mammals

Four species of primates were detected, and it is worth mentioning the records of two species. Firstly, our study confirmed the presence of Assamese Macaques from the PHR for the first time, which has been detected during both surveys, with a higher encounter rate in the 2020–2021 dry season. In the past, the Assamese Macaque was recorded only from two locations of the south-east and north-east hill forests. It was reported in 1995 from the Gazipur Tea Estate of Rajkandhi in the north-east, about 20 km south-west from our study site (Feeroz 2015b). No sighting reports of its occurrence appeared from that site afterwards. Interestingly, none of the protected areas in the northeast region are known to hold any population of this least known non-human primate (IUCN Bangladesh 2015). Secondly, we have three records of Phayre's Leaf Monkey which is Critically Endangered in Bangladesh. This species is confined to the south-east and north-east hill forests, and the deforestation of this area push the species over the brink to extinction (Kabir 2015). These records highlight the conservation significance of this forest for the primate in Bangladesh as one of the last remaining forests. It was also supported by our opportunistic records of a few groups of globally Endangered Western Hoolock Gibbon in the PHR.

Two ungulate species were detected during our survey, Northern Red Muntjac and Wild Boar. These two species were also recorded in two previous surveys (Weiskopf et al. 2018; Rahman et al. 2021). In Bangladesh, the Muntjac is categorized as Endangered due to limited distribution (Dey 2015), although globally it is identified as a Least Concern species (Timmins et al. 2016). In the PHR, the species was commonly detected in different environments from degraded areas to streambeds. The reasonable records produced the activity pattern of muntjac with the peaks in the morning, the evening and the night, which is consistence with previous studies (Gray & Phan 2011; Rasphone et al. 2020). On the other hand, Wild Pig showed crepuscular activity patterns that is inconsistent with previous studies where it was found diurnal (Rasphone et al. 2020). Wild Pig may reduce their diurnal activity when human disturbance is high (Keuling et al. 2008; Cremonesi et al. 2021; Aditya & Ganesh 2022), although the impact of human disturbance on activity pattern of Wild Pig is still not conclusive (Brivio et al. 2017). In the PHR, high human disturbance has

Image 1. Mammal species recorded during the 2019–2020 and 2020–2021 dry seasons in Patharia Hill Reserve, Bangladesh.
a—Golden Jackal *Canis aureus* | b—Fishing Cat *Prionailurus viverrinus* | c—Jungle Cat *Felis chaus* | d—Asian Golden Cat *Catopuma temminckii* | e—Leopard Cat *Prionailurus bengalensis* | f—Crab-eating Mongoose *Herpestes urva* | g—Indian Grey Mongoose *Herpestes edwardsii* | h—Ferret Badger *Melogale* sp. | i—Hog Badger *Arctonyx collaris* | j—Albino Hog Badger | k—Oriental Small-clawed Otter *Aonyx cinerea* | l—Yellow-throated Marten *Martes flavigula*.

Image 1. Mammal species recorded during the 2019–2020 and 2020–2021 dry seasons in Pathria Hill Reserve, Bangladesh.
m—Common Palm Civet *Paradoxurus hermaphroditus* | n—Large Indian Civet *Viverra zibetha* | o—Masked Palm Civet *Paguma larvata* | p—Small Indian Civet *Viverricula indica* | q—Northern Red Muntjac *Muntiacus vaginalis* | r—Wild Boar *Sus scrofa* | s—Assamese Macaque *Macaca assamensis* | t—Pig-tailed Macaque *Macaca leonina* | u—Rhesus Macaque *Macaca mulatta* | v—Phayre's Leaf Monkey *Trachypithecus phayrei* | w—Malayan Porcupine *Hystrix brachyura*.

been observed, but the magnitude of the hunting on these species remains unknown. Since the hunting pressure on ungulate species has been reported in other forest areas of Bangladesh and identified as the concern on the capacity for large carnivore conservation (Aziz et al. 2017), further work is required to investigate the hunting pressure and develop conservation strategy accordingly.

As an additional note, although not detected in our camera-traps, we observed a herd of five female individuals of Asian Elephants roaming in our study sites, which frequently cross the borders between Bangladesh and India (Talukdar et al. 2020a,b), highlighting the conservation significance of this transboundary forest areas.

Conservation implications

Our study revealed that the PHR is one of the richest mammalian hotspots in northeastern Bangladesh, with particular reference to the diversity of medium- and large-sized terrestrial mammals. The number of forest-based terrestrial carnivores detected is certainly higher than many protected areas in the northeastern region of the country (Aziz 2011; Rahman et al. 2021). The presence of Fishing Cat, Hog Badger, Ferret Badger, Oriental Small-clawed Otter and Assamese Macaque, among the others, is of particular importance considering their endangerment and rarity in Bangladesh.

However, the non-detection of large carnivore may suggest a worrying situation that the forest would result in unsuitable to accommodate large carnivores if no practical conservation measures are taken. The PHR is a highly disturbed habitat because of agricultural activities (e.g., betel leaf cultivation, orchards, paddy fields) in buffer zones. Elsewhere, reduction or local extinction of large carnivores has been observed within protected areas along with edge effects and habitat degradation originating from the land use change within and buffer zone of the protected area (e.g. Datta et al. 2008; Watson et al. 2015). Besides the demand for the agriculture land, illegal extraction of forest resources, cattle grazing and wildlife poaching are common in the PHR. Despite that the zoning strategy has been taken for the management of the PHR, anthropogenic pressure has been extended from social forestry zones. Intensive monitoring for wildlife poaching and illegal logging in the remaining natural patches within the PHR is needed. The restoration of the habitat is also urgently required, particularly in the areas close to the border. The remnant forest patches across the transboundary border of the PHR have been the last resort for mammals and have greater potential for the conservation of wildlife in general and mammalian fauna in particular. We recommend that the PHR be elevated to the status of protected area so that effective measures are ensured for the protection of wildlife and their habitats from further damage. Specifically, northeastern parts of Lathitila and southeastern parts of Madhabchhara forest beats should be demarcated for declaring a wildlife sanctuary for long-term conservation of wildlife and maintaining transboundary wildlife movement between Bangladesh and India. These conservation actions should be urgently considered given the rapid disappearance of forest habitats elsewhere in Bangladesh, and having the potential of large carnivores alongside diversified mammalian communities in the PHR.

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