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An ecological assessment of Hispid Hare *Caprolagus hispidus* (Mammalia: Lagomorpha: Leporidae) in Manas National Park, Assam, India

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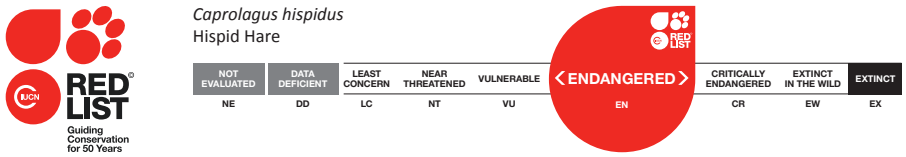
Abstract: This study of the Hispid Hare *Caprolagus hispidus* in the tall grassland habitat of Manas National Park, Assam during 2009–2010 is the first detailed assessment in northeastern India. We assessed the status, distribution, habitat use and key threats to this rare and little studied lagomorph species. After interviewing local forest staff, 20 grassland patches within a survey area of 2.65ha were selected and transects (50x2 m) laid randomly to determine the presence/absence of Hispid Hare by recording pellets and other indirect evidence. Hare presence was recorded in 17 grassland patches within transects dominated by *Imperata cylindrica* and *Saccharum narenga*. Hispid Hare preferred dry savannah grasslands to wet alluvial grasslands during winter and avoided recently burned patches due to lack of cover and food. The distribution pattern observed was clumped ($s^2/a = 6.2$), with more evidence of Hispid Hare presence in areas where ground cover was dense, dry and away from water sources. Population density was estimated at 381.55 individuals/km^2, which in comparison with other studies indicates that Manas National Park currently holds the highest density of Hispid Hare. Habitat loss due to overgrazing, unsustainable thatch harvesting, burning of grassland, weed invasion, encroachment and hunting were identified as key threats which must be addressed to ensure survival of this threatened species in the Park.

Keywords: Distribution, habitat use, Hispid Hare, India, Manas National Park, status, threats.



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Author Contribution: NKN being the team leader coordinated the entire study. He was involved in field data collection, data processing, data analysis and writing the paper. KM assisted NKN during field data collection, data entry and coordinated the awareness programmes.

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INTRODUCTION

Grasslands are highly dynamic ecosystems that provide goods and services to support flora, fauna and human populations worldwide, including a large number of endangered species (White et al. 2000). One such species is the Hispid Hare *Caprolagus hispidus* (Image 1) a Schedule I species of the Indian Wildlife (Protection) Act, 1972 (Molur et al. 2005; Maheswaran & Smith 2008). Hispid Hare is one of the only two lagomorph species which is listed in the Appendix I of CITES (Molur et al. 2005), the United States Endangered Species Act and the IUCN Red List (Maheswaran 2002). Historically, Hispid Hare was recorded in the tracts along southern Himalayan foothills from Uttar Pradesh (India) through Nepal and West Bengal to Assam (India), extending southwards as far as Dhaka (Bangladesh) (Blandford 1888; Dawson 1971). In the present day, Hispid Hare is known to exist only in a few isolated pockets across the formal range of its tall grassland habitats in India and Nepal. Populations are threatened by habitat destruction for agriculture, forestry, human settlement, flood control and irrigaton schemes, together with the adverse effects of dry season burning, overgrazing and harvesting of remaining tall grasslands (Bell et al. 1990). This species was thought to be extinct until it was rediscovered in 1971 in Barnadi Wildlife Sanctuary, Assam (Tessier-Yandell 1972; Oliver 1979, 1980). However, 37 years after its rediscovery the species remains neglected by researchers and conservationists in the region, and a lack of baseline information hampers conservation activities and status evaluation. Recently a rapid survey was conducted by the author within the North Bank Landscape (in nine protected areas of Assam and Arunachal Pradesh) that revealed physical evidence of Hispid Hare presence in Barnadi and D'Ering Wildlife Sanctuary (Nath 2009).

Manas National Park (MNP) with its 41% tall grassland habitat (Sarma et al. 2008) harbours a range of endangered wild animals along with Hispid Hare (Roy 1991; Lahkar 2008; Mary et al. 2013). Aside from indirect evidence and occasional sightings or capture reports, (Oliver 1979; Lahkar 2008; Choudhury & Kumar 2009) no detailed information was available about Hispid Hare in MNP. The present study was the first attempt at determining the status, distribution, habitat use and assessment of key threats for this rare species in MNP. This article is the outcome of a one year project on Hispid Hare carried out in MNP which was funded by the Conservation Leadership Program, UK (Nath et al. 2010).

Image 1. Hispid Hare *Caprolagus hispidus*

MATERIALS AND METHODS

Study area

Created in 1990, MNP is located (26^{0}35'–26^{0}50'N & 90^{0}45'–91^{0}15'E) in the foothills of the Bhutan Himalaya within the Chirang and Baksa districts of Assam, India (Fig. 1). Containing a complex of savanna grasslands, streams, rivers, standing water bodies and woodlands, MNP provides a perfect blend of mixed habitats for diverse flora and fauna of immense ecological importance. The vegetation is mostly comprised of tropical semi-evergreen forests, tropical moist and dry deciduous forests and alluvial grasslands (Jain & Hajra 1975). The grassland of MNP is the second largest in northeastern India (Choudhury 2003). The climate is warm with up to 76% relative humidity, mean annual rainfall is 3,330mm and temperatures range between 37^{0}C in summer and 5^{0}C in winter. The climate of the region can be divided into four distinct seasons on the basis of variation in rainfall, temperature and winds: winter (December–February), pre-monsoon (March–May), monsoon (June–September) and retreating monsoon (October–November) (Borthakur 1986).

Methods

The park staff has a close relationship with the forest, including knowledge of many resident animal species. Prior to the field survey we conducted interviews with forest guards regarding local hare species. The interview designed for this purpose was highly visual and employed high-resolution Hispid Hare photographs for easy and quick identification and we also used samples of Hispid Hare pellets during the interviews (Nath 2009). Based on information generated from the interviews, 20 grassland patches were selected for a Hispid Hare field survey

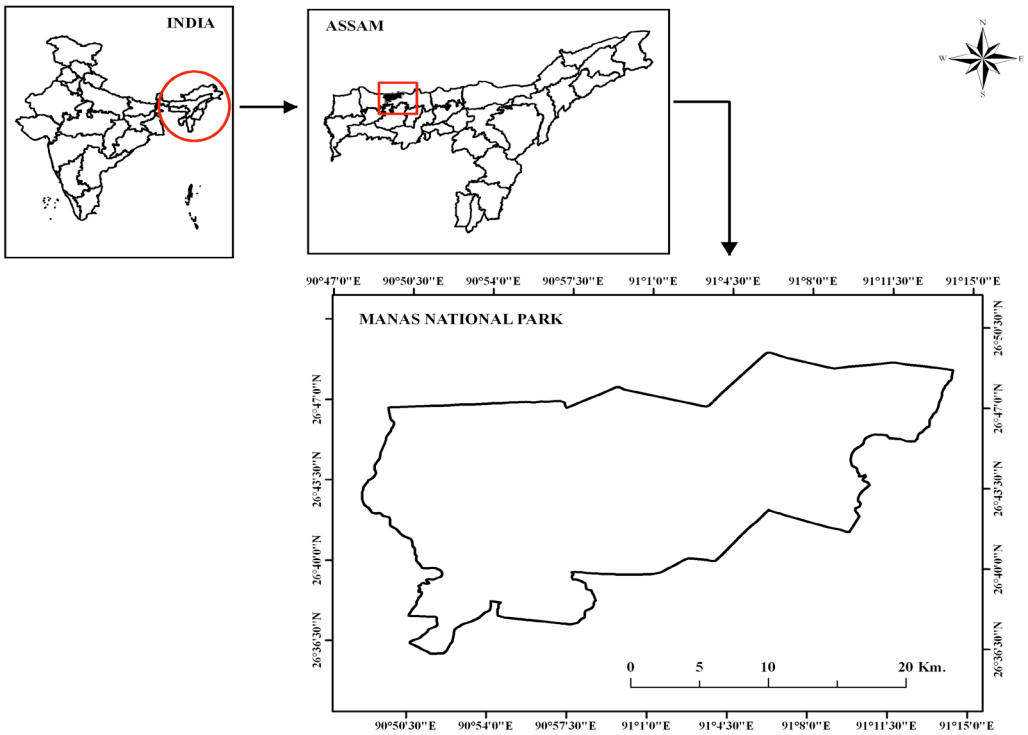

Figure 1. The study area - Manas National Park.

that collected data from December 2009 to mid-March 2010. Strip transects of 50x2 m^2 were laid randomly within selected grassland patches, and since direct sighting of Hispid Hare is difficult without using traps we mostly looked for indirect evidence that included pellets, feeding signs (grass cutting) and nests. Counts of fecal pellets have been used to answer basic ecological questions and to inform management decisions for a wide variety of species, including lagomorphs (Forys & Humphrey 1997; Langbein et al. 1999).

Each transect was surveyed only once. Whenever we encountered Hispid Hare pellets we counted all the pellets within the pile and measured pellet length and breadth (Maheswaran 2002) with a Digital Caliper to calculate the volume (Image 2). For direct identification of the species we followed a standard field guide (Menon 2003), while indirect evidence was identified with the help of available literature (Bell 1986; Bell et al.1990; Maheswaran 2002; Nath 2009). We also consulted local forest staff. Observations were recorded in a standard datasheet and all the relevant information (dominant grass species; soil condition and threats: fire/ weed invasion/cattle grazing/thatch harvesting/hunting; ground cover; distance to water source; total pellet piles (groups); size of pellet piles: total number of individual pellets within a single pellet group; status of pellet: fresh/ old; sign of other animals etc.) were noted, including the GPS location of the area surveyed. In 66 transects we conducted a preliminary vegetation assessment mostly to enumerate the weed and grass species. Mapping of the grasslands was done with satellite imageries of 2009 (IRS 1D LISS III) with the help of GIS & Remote Sensing using ERDAS Imagine 9.0 software.

Image 2. the lead author examining pellets on a transect

Data Analysis

Distribution pattern of Hispid Hare (based on pellet

data) in transects was analyzed by calculating the ratio of variance and mean (s^2/a) of total pellet piles observed in the transects following Odum (1971):

(s^2/a) = 1 (random distribution)

(s^2/a) < 1 (regular distribution)

(s^2/a) > 1 (clumped distribution)

Where, s^2 = variance = $1/n \Sigma (x-a)^2$; x = sample value; a = mean value

The volume of the pellets was calculated using the following formula (Das & Mukharjee 1996) – Volume = ½ pxy^2 (where x & y are the semi major and semi minor axis).

Habitat preference was calculated following Yadav et al. (2008):

$$\text{Habitat preference (HP)} = \frac{\text{Pellet present in each habitat type x 100}}{\text{Total pellet present in all the habitat type}}$$

For population density estimation we used only the fresh pellet data. To calculate pellet pile density and population density we followed the methodology of Aryal et al. (2012):

$$\text{Pellet density } (N) = \frac{\text{Total number of pellet piles observed}}{\text{Area of transect x Total number of transects}}$$

$$\text{Population density } (P) = \frac{\text{Observed pellet density in a specific time period}}{\text{Estimated defecation rate for a single animal}}$$

RESULTS

This study covered an area of 2.65ha of grassland using a total of 265 transects of which 102 were laid within dry savannah grasslands, 56 in wet alluvial grasslands and the remaining 107 transects in intermediate areas bordering both grassland types or the forest edge. Two-hundred-and-thirteen transects were surveyed before annual grassland burning and 52 after burning (within 1–2 weeks after burning), of which 23 possessed Hispid Hare pellets with none being fresh. Burning of grasslands started in the last week of December, but in the north and western part of MNP the fire did not spread far and most of the grassland patches selected for this study were standing until the end of February 2010.

Hispid Hare pellets were found in 17 grassland

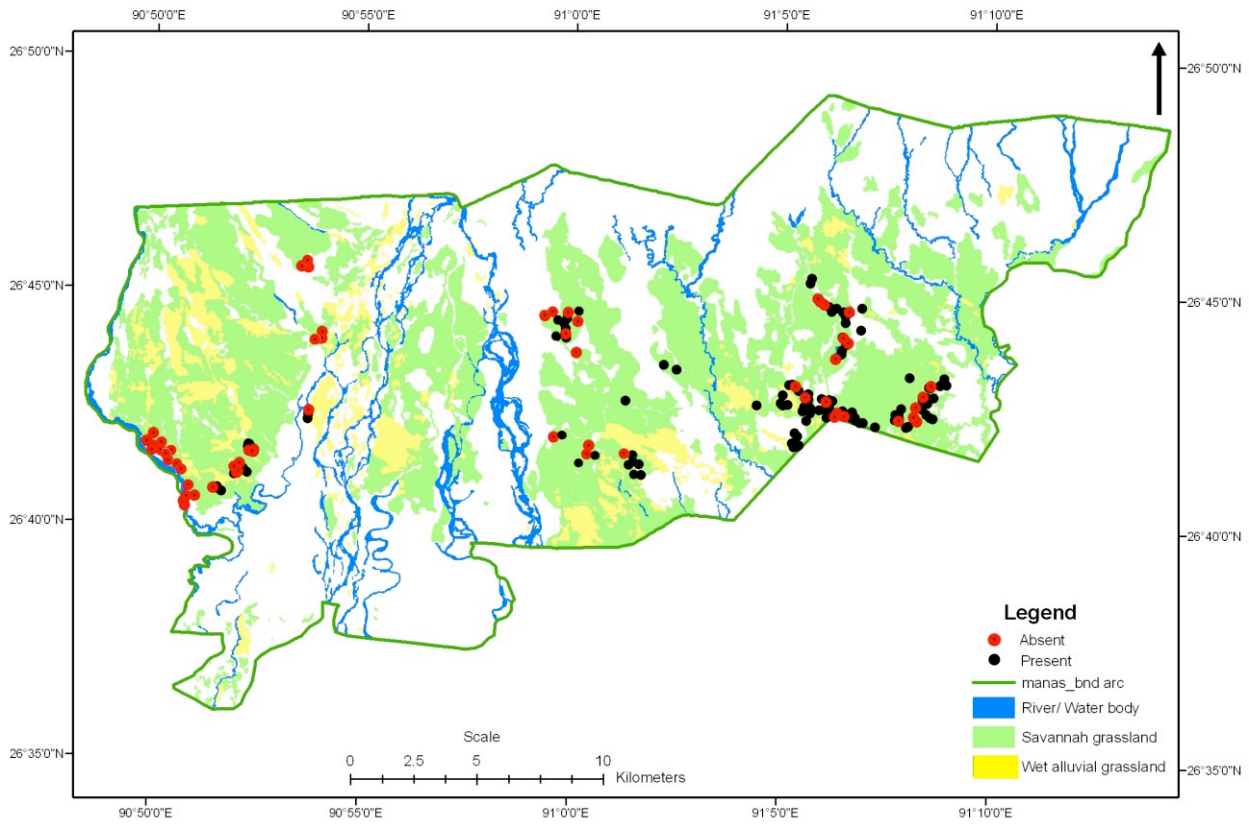

Figure 2. Map of Hispid Hare distribution within Manas National Park.

patches out of 20 selected. These areas include: Aagrang beat, Betbari beat, Bhuyanpara Range Office, Burhaburi, Charpoli, Dhanbil Beat, Digjari, Kanchanbari Beat (Balabari), Kaljar Beat, Kanchanbari Tower, Kuribeel, Lafasari, Moirakanda, Near Borbola, Rupahi Beat, Salbari and Ulubari (Moirakanda) (Fig. 2). In the grasslands near Kaljar Beat, Hispid Hare was sighted twice during the survey period (outside the transect).

Apart from pellets, feeding signs of Hispid Hare, both fresh and old were also found. Evidence of Hispid Hare feeding on three different species of grasses - *Saccharum narenga, Imperata cylindrica* and *Themeda arundinacea* was recorded. In all the cases, Hispid Hare consumed the inner core of the stem after carefully removing the outer bark.

During the field survey 11 nests were sighted, five in Aagrang, four in Bhuyanpara Range Office and two in Rupahi beat grasslands. The structures were shallow depressions of about 7.5–10.5 cm deep and 17.5–25.4 cm wide. The nest bed was carpeted with finely chopped grasses. Fresh pellets of both small (mean volume: 19.36m^3) and large sized (mean volume: 345.76m^3) were found nearby, suggesting presence of mother and young hares. Occurrence of small pellets was maximum in Aagrang grassland, followed by Bhuyanpara Range Office and Rupahi Beat grasslands. We recorded this breeding information in December 2009.

During the field survey, apart from Hispid Hare we recorded pellets from Indian Muntjac *Muntiacus vaginalis*, Hog Deer *Hyelaphus porcinus*, Sambar *Rusa unicolor* and Indian Hare *Lepus nigricollis*, as well as dung from Asian Elephant *Elephas maximus*, Asiatic Wild Buffalo *Bubalus arnee*, Gaur *Bos gaurus*, Wild Pig *Sus scrofa*, domestic cattle, and Common Leopard *Panthera pardus*; digging signs of Wild Pig were also recorded. Pellets of Indian Hare were found in transects where ground cover was less. Unlike Hispid Hare, we did not find Indian Hare pellets in thick tall grasslands, but rather in open areas and fallows.

Habitat preference (HP)

The preliminary assessment of vegetation conducted during this study revealed nine grass species, with significantly higher frequency of occurrence of *I. cylindrica* in the transects (χ^2_8= 194.36, *P*<0.001). The Relative Frequency (*RF*) of *I. cylindrical* was 34.21%, which was followed by *S. narenga* (*RF*= 24.74%) and *T. arundinacea* (*RF* = 18.42%) (Table 1). We found a higher frequency of pellets in the grasslands dominated by *I. cylindrica* (34.18%, n = 54), followed by *S. narenga* (25.32%, n = 40). Only a few pellets were found in grasslands dominated by *Arundo donax* (0.63%, n = 1) *and Phragmites karka* (0.63%, n = 1). The analysis of habitat preference revealed that Hispid Hare preferred dry savannah grasslands (HP = 64.56%, n = 102) more than wet alluvial grasslands (HP = 35.44%, n = 56). The GIS & Remote Sensing analysis of Hispid Hare habitat carried out during this study showed that the dry savannah grasslands occupied 32.4% (161.97km^2) and wet alluvial grasslands occupied 8.9% (44.37km^2) of the total grassland area of MNP.

Table 1. Frequency distribution of grass species recorded in the transects

	Grass species	Frequency (*F*)	Relative Frequency (*RF*)
1	*Imperata cylindrica*	98.48%	34.21%
2	*Saccharum narenga*	71.21%	24.74%
3	*Themeda arundinacea*	53.03%	18.42%
4	*Vetiveria zizanioides*	15.15%	5.26%
5	*Arundo donax*	3.03%	1.05%
6	*Cynodon dactylon*	15.15%	5.26%
7	*Elusine indica*	1.52%	0.53%
8	*Erianthus ravennnae*	22.73%	7.89%
9	*Phragmites karka*	7.58%	2.63%

Analysis of pellet data

Of the 265 transects, 146 (55.1%) had Hispid Hare pellets, with a total of 1675 pellet piles (fresh: 91; old: 1584) counted. In 22 transects we found both fresh and old pellet piles, in one transect we found only fresh, and only old pellet piles were found in 123 transects (χ^2_2= 174.82, *P*<0.001). Occurrence of fresh pellet piles in Bhuyanpara Range Office grassland was comparatively more than other grassland areas. The distribution patterns of pellet piles in transects were found to be of the Clumped type (s^2/a = 6.2).

For both fresh and old pellets, the size of pellet piles varied significantly. For fresh pellets, piles with 11–20 pellets occurred more frequently (χ^2_7= 89.66, *P*<0.001), while for old pellets piles having 21–30 pellets were more common (χ^2_{10}= 1484.3, *P*<0.001). The frequency of occurrence of pellets of different volume classes also varied, perhaps due to different animals living in different areas. The mean volume of the pellets measured was 250.41±1.23m^3 (at 95% C.I.) with volumes ranging from 13.66m^3 to 518.26m^3.

The occurrence of pellet piles was more in areas where ground cover was dense (80–100 %) (χ^2_4 = 3638.74, *P*<0.001). The soil condition where maximum concentration of pellets of Hispid Hare was found was

Table 2. Frequency distribution of weed species recorded in the transects.

	Weed species	Frequency (*F*)	Relative Frequency (*RF*)
1	*Mimosa pudica*	8.33%	4.43%
2	*Eupatorium odoratum*	27.38%	14.56%
3	*Leea aspera*	32.14%	17.09%
4	*Melastoma malabathricum*	70.24%	37.34%
5	*Mikania scandens*	50.00%	26.58%

dry and away from water sources.

Pellet density and population density

Overall pellet pile density of Hispid Hare we recorded during this study was 0.063/m^2. Within the selected grassland patches, pellet pile density varied from 0.005 to 0.133/m^2 (Appendix 1). Overall pellet density before burning was 0.087/m^2 and after burning 0.009/m^2. Fresh pellet pile density was 0.003434/m^2 (34.34/ha). The population density thus estimated was 381.55 individuals/km^2 (3.81 individuals/ha).

Assessment of key threats of Hispid Hare

Overgrazing: In the absence of grazing reserves, the local people of the fringe villages around MNP let their unproductive cattle (Cow, Buffalo, Goat and Sheep) inside the Park for grazing, which considerably degrades the grassland habitat and reduces cover for wild animals, particularly cover-dependent species like Hispid Hare. We found cattle grazing in 32.86% (n= 92) of the transects surveyed during this study. The density of fresh cattle dung piles was 199/ha. A preliminary survey (based on interviews) was carried out in the 61 fringe villages to the south of MNP during the same period for another research study, where we found an estimated cattle population of 15,541 (Buffalo: 369; Cow: 14,662; Goat & Sheep: 510). If we consider this entire stock of cattle graze inside MNP at some point in time, then the population density would be 31.08 cattle/km^2, which is huge.

Weed invasion: Weed invasion was recorded in 11.79% (n= 33) of the transects that we surveyed during this study. We recorded five weed species: *Melastoma malabathricum*, *Mikania scandens*, *Leea aspera*, *Eupatorium odoratum* and *Mimosa pudica*. The relative frequency of *M. malabathricum* was recorded the highest (*RF*: 37.34%) which was followed by *M. scandens* (*RF*: 26.58%) (Table 2). In MNP, invasion is also taking place due to *Bomax ceiba* tree saplings.

Unsustainable thatch harvesting: In MNP, Thatch collection by the locals starts in September and continues till the end of March. Besides their own household consumption, local people also harvest thatch grass to sell in the market. Thatch collection in an unsustainable manner may alter the grassland habitat in MNP. Thatch cutting was observed in 26.07% (n= 73) of the transects during this study.

Unscientific grassland burning: Grassland burning was recorded in 18.57% (n= 52) of the transects. The Park authority does not follow systematic patch burning of grasslands even though it is one of the most important recommended habitat management plans in MNP. Fire is sometimes also set by local graziers from the fringe villages to create new patches of grassland for their cattle. The burning of grasslands generally takes place between November and April. In the month of December we recorded uncontrolled fire in the northwestern part of Panbari Range of MNP.

Encroachment: Illegal encroachment is posing serious threats to Manas National Park. An area of 20km^2 of the total area of MNP is presently under encroachment. In the eastern part of MNP the encroached land was being used for cultivation whereas in the western part settlements were set up. Initiatives have been undertaken to evict the encroachers from time to time by the Park authority, however, not been able to achieve success so far.

Hunting: The local people in fringe villages located to the south of MNP are dominated by the Bodo tribe. Traditionally these people hunt wild animals for meat. Although during the study we did not find any evidence of hunting of Hispid Hare in particular, there is a high possibility as we recovered snare (noose) set for Hog deer and Wild Pig during field surveys in three different locations within the park.

DISCUSSION & CONCLUSION

This study was the first detailed assessment of Hispid Hare carried out in Assam. Maheswaran (2002) carried out a study in Jaldapara Wildlife Sanctuary (JWS), West Bengal on the ecology of this elusive species. During this study we gathered details on status, distribution and habitat use of Hispid Hare and we also assessed key threat factors for this species in MNP. Not all grasslands could be surveyed, and we covered an area of only 2.65ha out of the total grassland area of 206.34km^2 in MNP. Our efforts were limited by the inaccessibility of many grassland areas and significant risks of attack

by potentially dangerous animals including Asian Elephant, Greater One-horned Rhinoceros *Rhinoceros unicornis*, Tiger *Panthera tigris*, Asiatic Wild Buffalo and Gaur. Nevertheless, the information generated during this preliminary ecological study provides baseline information, which will help in planning future studies and in guiding efforts by the park authority to set up of effective conservation measures for this rare, endangered species.

Our survey covered both pre and post burning seasons, however, most of the grassland patches selected for this study remained unburnt during the study period. We did not find fresh pellets in transects surveyed 1–2 weeks after burning, which perhaps due to lack of cover and food Hispid Hare avoided. Maheswaran (2002) also found that Hispid Hares use recently burnt grassland patches less than tall grassland areas. We did not attempt any diet analysis from pellets, but evidence of Hispid Hare feeding was recorded during the field survey. We observed feeding sign (grass cutting) on three species: *S. narenga, I. cylindrica* and *T. arundinacea*. Oliver (1980) mentioned that the Hispid Hare's diet mostly consists of thatch shoots and roots, which are bitten off at the base and stripped of the outer sheaths prior to consumption, but diet may vary according to season, availability of food and locality. Aryal et al. (2012) recorded nineteen (19) plant species (*Saccharum spp.* and *I. cylindrica* contributed >55%) in the diet of Hispid Hare during their study in Suklaphanta Wildlife Reserve (SWR), Nepal. Tandan et al. (2013) recorded 23 plant species in Bardia National Park (BNP) Nepal, with the five most preferred being: *S. spontaneum*, *I. cylindrica*, *Desmostachya bipinnata*, *Cynodon dactylon* and *S. munja,* which together constituted more than 85% of the diet. Tandan et al. (2013) further showed that the composition of plant species in the Hispid Hare diet was proportional to their presence in habitats.

During the field survey in December we sighted 11 nests, with fresh pellets of small and large size nearby, suggesting the presence of adult and young animals. In Nepal, pregnant females were captured in January and February (Bell 1986, 1987; Bell et al. 1990), while Maheswaran (2002) reported small (<6mm) and large pellets together in April and in June. From these reports it can be concluded that the breeding season of Hispid Hare probably varies from place to place, as Maheswaran (2002) postulated.

The grassland habitat in MNP is dominated by *I. cylindrica* (Lahkar 2008), which we observed to be predominant in Hispid Hare habitats. We found Hispid Hare preferred dry savannah grasslands to wet alluvial grasslands during the winter, similar to the observations of Yadav et al. (2008) in SWR, who also reported that Hispid Hare use wet alluvial grasslands more during the summer. Our habitat analysis revealed that in MNP the dry savannah grasslands occupied 32.4% and wet alluvial grasslands occupied 8.9% of the total grassland area of MNP. A comparison of these data with Sarma et al. (2008) showed that in MNP the grassland habitat decreased by 13% during the period 2006–2009, the dry savannah grassland decreased by 1% and wet alluvial grassland by 12%. Possible reasons for this decline include siltation of water bodies, invasion by weeds, overgrazing, unsustainable thatch harvesting and invasion of *Bombax ceiba* saplings. The grasslands in MNP should be intensively managed with suitable habitat interventions so that the desired species composition is attained. This is particularly important because these grasslands harbor Hispid Hare and many other threatened species such as Pygmy Hog *Sus sylvanius*, Greater One-horned Rhinoceros, Tiger, Swamp Deer *Rucervus duvaucelii*, Asiatic Wild Buffalo, Asian Elephant, Bengal Florican *Houbaropsis bengalensis* and Swamp Francolin *Francolinus gularis* (Lahkar 2008).

We found that Hispid Hare showed a clumped distribution typical of populations in natural habitats (Odum 1971), indicating that hares use different patches during certain periods of the year. We found that the occurrence of pellet piles was more in areas where ground cover was dense, soil condition was dry and away from water sources, as observed by Yadav et al. (2008) in SWR. Our estimated current population density of 3.81 individuals/ha is considerably larger than the 0.087/ha reported by Maheswaran (2002) in JWS (determined from live capture data). In SWR, Bell (1987) reported a mean population density of 6.10 individuals/ha, Yadav et al. (2008) reported 1.01/ha, and recently Aryal et al. (2012) reported 0.06 individuals/ha, with a maximum total SWR population of 219±40. Tandan et al. (2013) reported a density of 0.45 individuals/ha in BNP before burning and 0.967/ha after burning. Comparing these studies, it appears that MNP has the greatest current Hispid Hare population density.

Despite its apparent robustness, the MNP Hispid Hare population faces multiple threats. Uncontrolled cattle grazing is frequent in protected areas across the tropics (Piana & Marsden 2014), and many grasslands have been destroyed or extensively modified (Watkinson & Ormerod 2001). We recorded cattle grazing in >30% of transects studied, consistent with a cattle population of >15,500 in villages around MNP. This represents a considerable potential pressure on

MNP grasslands, where regulation of grazing is of utmost importance. Another emerging threat is weed invasion (Ditomaso 2000). In addition to invasion by *B. ceiba* saplings we identified five other weed species in the grasslands of MNP in order of decreasing frequency: *M. malabathricum, M. scandens*, *L. aspera*, *E. odoratum* and *M. pudica*. Invasive species have been gradually changing the structure of MNP grasslands (Lahkar et al. 2011), and while invasion of *B. ceiba* saplings is a natural succession, if allowed to proceed unchecked the result will be conversion of grasslands to woodlands and loss of Hispid Hare habitat (Maheshwaran & Kumar 2008). In MNP, a preliminary study was conducted by Lahkar (2008) on density of invasive species in grasslands of the Bansbari Range. He recorded seven weed species, noting *E. odoratum* as the fastest-spreading species that posed the main challenge to the Park authority. Recognizing the seriousness of the problem, the 31st session of the world heritage committee held in Christchurch in 2007 suggested that the Forest Department of Assam develop an independent management plan to control invasive species (Lahkar et al. 2011). The US Fish & Wildlife Service in partnership with Aaranyak (NGO) has already initiated a project which aimed at developing, implementing and validating a monitoring and control program to address the invasive species *Mikania* and *Eupatorium* in MNP (USFWS 2013).

Hispid Hares need cover for breeding and to protect against predators, and removal of tall grasses for thatch substantially reduces available cover. Some thatch grass species have also been identified as food plants for Hispid Hare, and the removal of grass biomass by fire and cutting has been demonstrated to be deleterious to affected populations (Bell et al. 1990). Thatch collection by locals was observed in >25% of transects studied, and since the practice of harvesting thatch for sale in local markets is likely to be non-sustainable, this practice should be strictly monitored and regulated by the forest department. The annual dry season burning of grasslands is another key threat to Hispid Hare, since its breeding coincides with the burning season (Bell 1986; Bell 1987). Of the three main grassland burning periods: early (November–December), mid (January–Feb) and late (March–April), Lahkar (2008) observed that late burning was most deleterious in terms of animal mortality and habitat loss. Gillon (1983) pointed out that early season fires stimulate productivity of grasslands while late season fires depress it. Considering these findings, an early "patch-mosaic burning technique" can be recommended for MNP, leaving sufficient habitat unburned in locations of high Hispid Hare abundance. During our field survey we also recovered hunting snares set by people from local villages dominated by the Bodo tribe, who traditionally hunt wild animals for meat. While we have no specific information, it is highly likely that Hispid Hare are being taken by hunting.

In summary, Hispid Hare populations in MNP are threatened by multiple factors, with habitat loss having the highest priority. A proper land use plan is required to check further encroachment, together with eco-development initiatives to improve the livelihood of local people, awareness/education programs to promote sustainable utilization of natural resources, and active involvement of the local community in conservation activities. These initiatives will substantially reduce anthropogenic pressures in MNP and help to ensure the survival of Hispid Hare in the area.

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Appendix 1. Selected grassland patches within Manas National Park with their GPS locations, area surveyed and Hispid Hare pellet pile density/m².

	Grassland	GPS location	Total area surveyed (m²)	Pellet pile density/m²
1	Aagrang beat	26°42'76.06"N & 91°08'52.04"E	1900	0.075
2	Betbari beat	26°43'10.01"N & 91°08'49.70"E	1300	0.093
3	Bhuyanpara Range Office	26°42'32.60"N & 91°06'41.50"E	2700	0.133
4	Borbola	26°43'56.80"N & 90°53'58.80"E	300	No pellet
5	Burhaburi	26°41'55.00"N & 90°59'35.10"E	800	0.055
6	Charpoli	26°43'44.00"N & 91°00'05.80"E	600	0.038
7	Dhanbil beat	26°41'24.60"N & 91°06'02.10"E	2100	0.114
8	Digjari	26°42'39.00"N & 91°08'12.90"E	1500	0.073
9	Gabhorukhunda	26°45'27.00"N & 90°53'39.60"E	300	No pellet
10	Kanchanbari beat (Balabari)	26°44'45.20"N & 91°06'16.50"E	3000	0.073
11	Kaljar beat	26°41'49.80"N & 91°05'31.30"E	600	0.072
12	Kanchanbari Tower	26°44'33.10"N & 90°59'52.60"E	1100	0.072
13	Kuribeel	26°41'21.70"N & 91°01'37.60"E	900	0.017
14	Lafasari	26°40'44.40"N & 90°51'34.60"E	800	0.024
15	Moirakanda	26°41'30.20"N & 90°52'26.10"E	1200	0.005
16	Near Borbola	26°42'24.60"N & 90°53'43.50"E	700	0.023
17	Rupahi beat	26°42'38.10"N & 91°05'32.70"E	2000	0.089
18	Salbari	26°41'33.00"N & 90°49'42.20"E	1200	0.018
19	Sukanjani	26°40'35.10"N & 90°50'47.10"E	2800	No pellet
20	Ulubari (Moirakanda)	26°41'30.40"N & 90°52'24.30"E	700	0.031

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