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Current population status of the endangered Hog Deer *Axis porcinus* (Mammalia: Cetartiodactyla: Cervidae) in the Terai grasslands: a study following political unrest in Manas National Park, India

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Abstract: The Endangered Hog Deer *Axis porcinus* has experienced drastic population declines throughout its geographical range. There is limited knowledge of its current population status, particularly from northeastern India. In this study the population density of Hog Deer was assessed in Manas National Park, which was a deer stronghold prior to the armed conflict that lasted for almost two decades, resulting in depressed deer populations. With the cessation of conflict, efforts were invested by both government and conservation organisations for the recovery and conservation of charismatic fauna in the park. Studies on Hog Deer populations, however, were lacking and thus reliable information on current status is unavailable. Current population status and threats faced by Hog Deer were assessed to aid informed conservation decisions. Distance sampling techniques (line transects) were applied in the grassland habitat during the dry season of two consecutive years. The estimated Hog Deer density was 18.22±3.32 km^{-2}. The potential threats to Hog Deer identified in Manas include habitat loss, habitat degradation due to spread of invasive plant species, illegal hunting, and other anthropogenic disturbances. Our study suggests that the Hog Deer population, though reviving, needs immediate conservation attention.

Keywords: Armed conflict, geographical range, invasive species, population density.

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Author contribution: AS, BPL and SAH developed the concept and designed the framework. SAH provided valuable inputs in statistical analysis and manuscript writing. AS and BPL acquired the resources. AS collected data, performed statistical analysis and interpretation, manuscript writing and revisions. BPL and SAH supervised the project and contributed to the manuscript.

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INTRODUCTION

The Hog Deer *Axis porcinus*, historically distributed across South and Southeast Asia, underwent a drastic range-wide decline during the mid and late 20th Century (Brook et al. 2015; Timmins et al. 2015). Subsequently, *A. porcinus* was categorised as an Endangered species by the IUCN in 2008 (Timmins et al. 2015). Despite being an Endangered species, it is one of the least studied mammals and its range-wide decline was mostly overlooked (Brook et al. 2015). The southeastern Asian population is locally extinct in most countries, including China, Lao PDR and Vietnam (Ohtaishi & Gao 1990); the only wild populations remain in Cambodia and Myanmar (Brook et al. 2015; Lwin et al. 2016). In southern Asia, with a declining population trend, the Hog Deer is mostly confined to protected areas (Karanth & Nichols 2000; Biswas 2004; Odden et al. 2005). Timmins et al. (2015) recommended that estimating population abundance was important in assessing the conservation status of *A. porcinus*. Though deer population estimates are available for few well-managed protected areas, mostly in Nepal (Odden et al. 2005; Bhattarai & Kindlmann 2012; Lovari et al. 2015), data from other areas of southern Asia are lacking.

The Hog Deer (Image 1) is a grassland obligate (Dhungel & O'Gara 1991; Odden et al. 2005), primarily threatened by habitat degradation or loss and illegal hunting. It is an important prey for large carnivores (Stoen & Wegge 1996; Lovari et al. 2015), and thus plays a vital ecological role. India is one of the strongholds of *A. porcinus* populations in southern Asia, although historically it has received little attention and available information is mostly anecdotal (Biswas 2004). To implement rational conservation measures, reliable estimates of population abundance are fundamental,

Image 1. Hog Deer *Axis porcinus*,

and their lack can undermine the entire process (Lopez-Bao et al. 2018). Thus the current population status of *A. porcinus* was assessed and potential threats to the population in Manas National Park in Assam were documented.

Manas National Park (henceforth, Manas) in northeastern India harboured a population of approximately 10,000 Hog Deer until the 1980s (Tikader 1983), and armed conflict in the region from the mid-1980s to 2003 lowered the population density (Goswami & Ganesh 2014). The instability resulted in habitat degradation, destruction of park infrastructure and poaching/hunting in the absence of normal law and order. With the restoration of peace, conservation efforts were implemented to safeguard remaining wildlife populations (UNESCO 2005). The cessation of civil unrest facilitated access to Manas by various conservation organisations that work with management authorities to conserve wildlife and promote species recovery. Most of the management and conservation inputs have focussed on securing and conserving charismatic megafauna like One-horned Rhinoceros *Rhinoceros unicornis* and Bengal Tiger *Panthera tigris*, which are apex species in the ecosystem and iconic species for conservation. In comparison, lesser-known mammals like the Hog Deer have received little attention. With about 40% grassland habitat (Das 2018), Manas represents one of the last remnant patches in western Assam that can support grassland obligates such as One-horned Rhinoceros, Hog Deer, Hispid Hare *Caprolagus hispidus*, Pygmy Hog *Porcula salvania*, Bengal Florican *Houbaropsis bengalensis*, Swamp Deer *Rucervus duvaucelii*, Asiatic Water Buffalo *Bubulas arnee*, and others (Lahkar 2008). These grasslands are under threat from invasion by alien plant species, mostly by *Chromolaena odorata* and *Mikania micrantha* (Lahkar et al. 2011; Nath et al. 2019), agricultural encroachment, and cattle grazing (Sarma et al. 2008), which may have had an impact on Hog Deer population abundance.

It is evident that Hog Deer and their habitat in Manas deserve immediate conservation attention. Goswami & Ganesh (2014) attempted to estimate the population density of herbivores immediately after the cessation of the conflict, but their study had limited observations. The authors conducted line transect sampling on foot, which may have an influence on the detection probability (Wegge & Storaas 2009). This is the first intensive study from Assam that focussed on estimating the population density of Hog Deer. This provides an important insight regarding the current status of this threatened species and the need for management intervention for its long-term conservation.

MATERIALS AND METHODS

Study area

The study was conducted in Manas National Park (26.722^{0}N & 91.043^{0}E), which forms the core of the Manas Tiger Reserve in the northeastern Indian state of Assam (Figure 1). It lies along the foothills of the Himalaya,

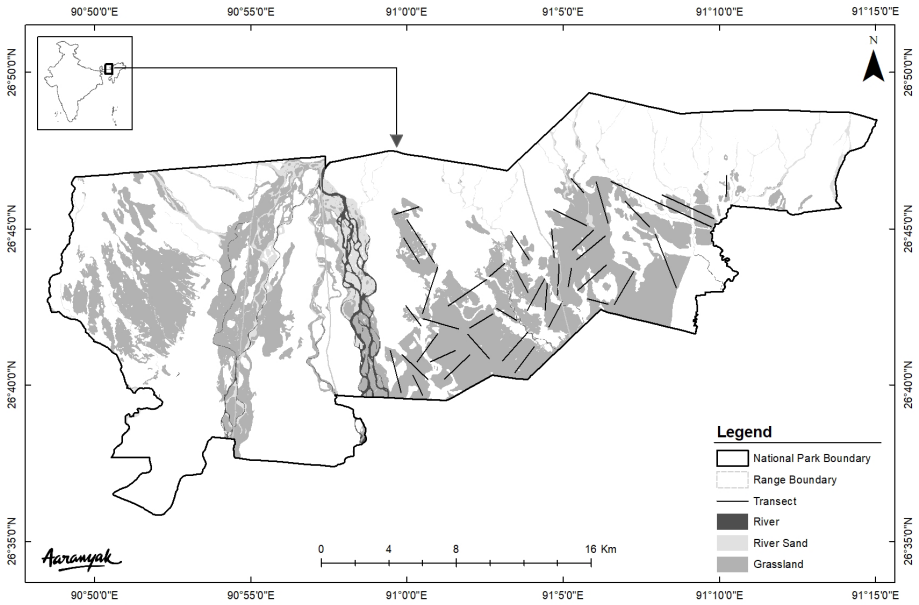

Figure 1. Manas National Park and lay-out of line transects in the grassland habitat in Manas. (Map Source: Aaranyak).

and is contiguous with the Royal Manas National Park of Bhutan to the north, bounded by villages to the south, by Daodhara and Batabari reserve forests to the east, and reserve forests to the west. The park comprises an area of 519km^2 (Sarma et al. 2008) and has a predominantly flat terrain. Broadly, the vegetation of Manas is classified as sub-Himalayan alluvial semi-evergreen forest, east Himalayan mixed moist and dry deciduous forests, the commonest type, and grasslands (Champion & Seth 1968). The grasslands are further classified into dry savannah grasslands and wet alluvial grasslands. These grasslands occur in seven major grass assemblages which harbour many threatened grassland obligates (Lahkar 2008). Manas harbours a rich faunal assemblage, with 60 species of mammals, around 470 avian species, and 42 species of herpetofauna. The climate of Manas is warm and humid, with rains from mid-March to October; most rain falls during the monsoon months from mid-May to September and November to February is relatively dry (Borthakur 1986).

In Manas, political stability was attained with the formation of Bodoland Territorial Autonomous Districts (BTAD) in 2003, and subsequently the conservation intervention gained momentum, such as with a Rhino restocking programme (Barman et al. 2014). Nevertheless, instances of occasional conflicts were prevalent in the western Range (Panbari) until 2016 (Lahkar et al. 2018). Therefore, the study was restricted in the central (Bansbari) and eastern (Bhuyanpara) administrative ranges of the park which had one such incident in 2014.

Field Survey

The population density of Hog Deer was derived through distance sampling (Buckland et al. 2004), which is established as a standard method and has been adopted widely to generate herbivore densities across various habitats in the tropical and temperate ecosystems in Asia (Varman & Sukumar 1995; Khan et al. 1996; Biswas & Sankar 2002; Jathanna et al. 2003; Wegge & Storass 2009; Wang 2010; Bhattarai & Kindlmann 2012; Goswami & Ganesh 2014; Lovari et al. 2015). The entire study area was overlaid with 2 x 2 km grid and stratified random sampling was adopted. Line transect surveys from elephant back (Wegge & Storaas 2009) were conducted in the grids with grassland cover as the species is a grassland obligate (Dhungel & O'Gara 1991; Odden et al. 2005) during the dry season of 2014–15 (henceforth, 2015) and 2015–16 (henceforth, 2016). A total of 75 transects were sampled, covering a total distance of 206.56km. Spatial replicates were used, as Hog Deer sightings were relatively low in Manas (Krishna et al. 2008) and transect lengths varied from 2 to 5 km. During the elephant transects, the Mahout (elephant driver) and one observer detected and counted the animals. For each detection the radial distance of the animal to the observer and sighting angle were measured using a range finder and a compass respectively.

Data Analysis

Initially, the encounter rate of Hog Deer per transect per year was compared to investigate whether there is any significant difference between them using a Z-test. As there was no significant difference between both years ($z=0.05$, $P > 0.05$, $n1= 35$, $n2 =40$), the data from two consecutive years were pooled to estimate the Hog Deer population density in the park using programme DISTANCE 7.1. Conventional distance sampling (CDS) approach in DISTANCE programme was used to derive Hog Deer density estimates (Buckland et al. 2001). Exploratory analyses were carried out to check for evasive movement before detection, heaping effect, and truncation of observation outliers (Buckland et al. 2001). The data were grouped into unequal distance bins, and chi-square goodness-of-fit values (the lowest) were considered to select the interval combination (Buckland et al. 2004; Zamboni et al. 2015). The data beyond the distance of 45m were truncated as they were outliers for better model fitting. The probability of detection was estimated using six models recommended by Buckland et al. (2001) combining probability density function (uniform, half normal and hazard-rate) with adjustments (cosines, simple and hermite polynomials). The models were selected based on the criterion of lowest AIC as generated by the program. The estimates were generated with standard error, the coefficient of variation and confidence intervals. Hog Deer density (D) was estimated, and approximate population size (N) was computed based on the size of the habitat area.

To derive the population structure and age-sex-ratio of Hog Deer, intensive surveys were conducted in the entire park and computed based on percentage sightings. Data were recorded both during the line transect sampling and opportunistic sightings over a period of two years on group size and composition. For each detection, the animals were classified into the following age-sex categories; fawn (1–12 months), yearlings (13–24 months) and adults (>24 months) based on Dhungel & O'Gara (1991) classification. Based on the sightings, adult male to adult female and doe to fawn ratio was calculated. The data from both the years were pooled as there was no significant difference between the adult

male (z=0.49, P>0.05, n1=56, n2=68) and adult female (z=1.65, P>0.05, n1=56, n2=68) categories between the years. Furthermore, a significant difference between the percentage of adult male and female in a group was tested using z statistic. The percentage data was transformed using arcsine transformation and analysed using MS Excel.

RESULTS

A total of 202 sightings of Hog Deer were made along the 206.56km of transects during the two years sampling period. Of these, 56.20% of the sightings were from the central range and 43.80% from the eastern range. The overall density of Hog Deer in Manas was estimated to be 18.22 ± 3.32 km^{-2} (CV = 18.27%, 95% CI = 12.72–25.09). Based on comparisons of the lowest AIC values, the uniform key function with cosine adjustment best described the Hog Deer data (Figure 2). The result, with estimated density, percent coefficient of variation, 95 % confidence interval and AIC is summarised in Table 1. On extrapolating the population density of 18.22km^{-2} to the available grassland habitat in the park (194.57km^2, Das 2018), the population size of Hog Deer was estimated to be 3,545 ± 647.64 (CV = 18.27%, 95% CI = 2,475–5,077).

To understand the age structure of Hog Deer population, the percentage of different group types was calculated based on the number of animals detected during the line transect and other opportunistic sightings for both the years. In a few instances (4.59%), though, the sex of the animal could not be identified. The groups were classified as solitary-consisting of single animal, small (2–3 animals), medium (4–6 animals) and large (>6 animals) groups (modified from Biswas 2004). Most of the animals occurred solitary (50.79%), 36.50 % occurred in small groups, 10.31% in medium groups, and only 2.38% in large groups. The mean group size of Hog Deer is estimated to be 1.81 ± 0.11. The observed overall sex ratio in Manas, of adult male to adult female to fawn is 47.01:100:17.88. There is a significant difference between the adult male and female percentage in a group (z= 4.72, P<0.01, n1=n2=125).

DISCUSSION

Our study suggests that the current estimated Hog deer density in Manas differs substantially from that of the previous study which reported a density estimate of 4.59km^{-2} (Goswami & Ganesh 2014). One of the possible reasons is the difference in the line transect sampling method that the two studies have adopted. Sampling in grassland habitats on foot may influence the detection probability and underestimate the population abundances of species like Hog Deer (Wegge & Storaas

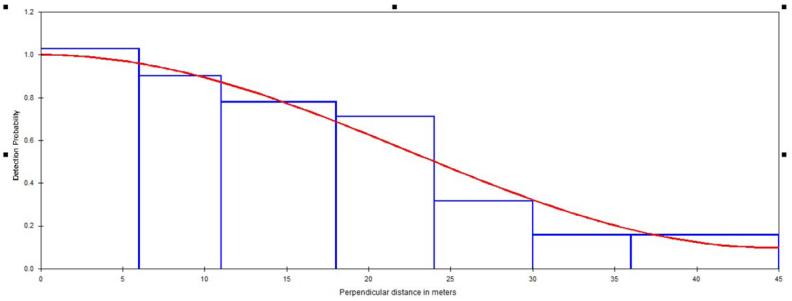

Figure 2. Distance data for Hog Deer *Axis porcinus* truncated at 45m, and fitted with the uniform cosine model.

Table 1. Summary of overall Hog Deer density estimate in six models as recommended by Buckland et al. (2001).

Parameter	Uniform + Cosine	Uniform + Simple polynomial	Half normal + Cosine	Half normal + Hermite polynomial	Hazard rate + Cosine	Hazard rate + Simple polynomial
Density km^{-2}	18.22	18.12	18.86	18.86	17.57	17.57
Percent Coefficient of variation	18.27	19.07	19.26	19.26	20.14	20.14
Upper CI	25.09	26.25	27.51	27.51	26.06	26.06
Lower CI	12.72	12.50	12.93	12.93	11.84	11.84
AIC	375	376.79	375.07	375.07	376.54	376.54

Table 2. Estimates of Hog Deer density across southern Asia.

Location	Habitat type	Density of Hog Deer (km^{-2})
Chitwan National Park, Nepal	Savanna grassland	15.5–19.1
Bardia National Park, Nepal	Floodplain grassland	77.3
Kaziranga National Park, India	Floodplain grassland	38.6
Sukhlaphanta Wildlife Reserve, Nepal	Grassland	4.1 (2010) and 11.6 (2011)
Keibul Lamjao National Park, India	Grassland/phumdis	2.51
[1]Manas National Park, India	Grassland	4.59
[2]Manas National Park, India	Grassland	18.22

Sources: Chitwan (Dhungel & O'Gara 1991), Bardia (Odden et al. 2005); Kaziranga (Karanth & Nichols 2000); Sukhlaphanta (Lovari et al. 2015); Keibul (Angom 2012); Manas 1 (Goswami & Ganesh 2014); Manas 2 (present study).

2009). Therefore, we conducted line transect surveys from elephant back following Wegge & Storaas (2009), which may have led to higher Hog Deer density estimate than the previous study. During the All India Tiger Monitoring exercise, the attempt to estimate prey density in Manas with an effort of 134km was hindered due to low number of observations (Jhala et al. 2015). The line transect sampling was conducted on foot, which might have resulted in lesser sighting records due to tall and dense vegetation. Therefore, sampling from elephant back in the grassland habitat in Manas is recommended for all the future population estimates of Hog Deer. In this study the estimated population size of Hog Deer is 3,545, considerably different from the previous estimate of 1,626. The sampling protocol to used derive this estimate was not clear. Nonetheless, our study finding indicates a possible recovery of the Hog Deer population over the years with the cessation of the conflict which can be attributed to enhanced protection and anti-poaching measures.

The Hog Deer population in Manas is female-biased. The sex ratio favouring the females is a characteristic of polygamous species (Dhungel & O'Gara 1991). Seidensticker (1976) reported a sex ratio of 51 males: 100 females: 24 fawns, whereas Mishra (1982) observed a ratio of 59 males: 100 females: 55 fawns. A similar sex ratio was also observed by Dhungel & O'Gara (1991) (56 males: 100 females). The mean group size of Hog Deer in Manas is similar to that of Chitwan (1.8, Dhungel & O'Gara 1991), but lower than reported in Jaldapara Wildlife Sanctuary (2.68, Biswas 1999). Hog Deer is primarily a solitary cervid (Odden & Wegge 2007), but congregates in small groups while feeding. During our study period we mostly documented Hog Deer singly or in small groups. Large groups comprising of more than six individuals were observed less frequently (12.69%). Biswas (1999) reported that 41% of animals were solitary, 56% occurred in small to large groups and only 3% occurred in very large groups (>10 animals) in Jaldapara. The largest congregation observed was of 33 animals, feeding on the fallen flowers of *Gmelina arborea* during the dry season in Manas.

Prior to the armed conflict, Manas harboured an abundant Hog Deer population of approximately 10,000 animals (Tikader 1983). The absence of empirical data on Hog Deer populations before and after the conflict limits our efforts to quantify the population change; interactions with experts who have worked in the area during the 1980s suggest that the population has declined sharply, more than 70% (Goutam Narayan pers. comm. December 2017). The local extinction of One-horned Rhinoceros (Talukdar 2003), depressed population of Swamp Deer (Das et al. 2009; Borah et al. 2013), Pygmy Hog (Bibhuti P. Lahkar pers. obs. 19.xii.2017) and Bengal Florican (Namita Brahma pers. comm. 19.xii.2017) due to the armed conflict (Lahkar et al. 2018), reflects that the grassland species declined drastically because of selective hunting by both opportunistic hunters and the anti-government forces (Goswami & Ganesh 2014). The possible drivers of Hog Deer decline are habitat degradation & reduction and illegal hunting. The grasslands which Hog Deer prefer have reduced in area over the last four decades (Sarma et al. 2008; Das 2018). The grassland patches such as 'Pahufield' area, 'Rhino camp' area and the grasslands particularly near the southern boundary of the park, mostly in the central range, which were prime Hog Deer habitats (Bibhuti P. Lahkar pers. obs. February 2002) are heavily infested with invasive plants such as *Chromolaena odorata* and *Mikania micrantha* (Nath et al. 2019). There is also livestock grazing pressure in the grassland (approximately 2000 cattle per day graze inside the park during the dry season, (Alolika Sinha pers. obs. 20.iii.2017) and can lead to severe competition for forage.

Trapping of Hog Deer for consumption using snares in the fringe village is not uncommon (Alolika Sinha pers. obs. 25.iii.2017). During the study period, four incidents of Hog Deer hunting were recorded in the fringe villages. This may underestimate hunting incidents, since many go unreported. We also found snares along the southern boundary of the park, which were possibly set-up to trap Hog Deer, other small mammals (e.g., hares), and birds. Another emerging threat to the species in Manas is attack by feral dogs. During the dry season, when the Hog Deer congregate to feed on *Gmelina arborea* flowers and fruits in the central range near an area called 'second gate', they are attacked by the feral dogs. We recorded six incidents over a period of two months (February-March 2016) where the feral dogs attacked and killed deer, although the dogs were not seen eating them. A multitude of factors like habitat degradation, occurrence of invasive plant species, and anthropogenic disturbances might affect the Hog Deer population in Manas. The influence of these various factors on Hog Deer population can be drawn more conclusively, upon long-term monitoring of its population and grassland habitat.

The present Hog Deer estimate, when compared with those from other areas in southern Asia revealed that Manas is an area of intermediate deer density (Table 2). Nevertheless, with the restoration of governance and administration, the management intervention improved substantially. A major step was the conversion of the former poachers/hunters into conservation volunteers and engaging them in regular patrolling of the park along with the forest personnel. Hog Deer are known to occur in high density in other well-protected areas (Table 2) (Karanth & Nichols 2000; Odden et al. 2005). The grasslands in Manas are one of the last remnant habitats in the eastern Terai (Lahkar 2008) and crucial for Hog Deer survival in the region (Biswas 2004). The scope of Hog Deer persistence beyond the National Park is limited due to scarcity of potential habitats and high anthropogenic pressure on these habitats.

Our study highlights the current population status of this threatened species, and we have documented potential threats to Hog Deer in Manas. This baseline population estimate will be useful to monitor future changes and conservation of Hog Deer in one of the high-value conservation landscapes. Manas is the most promising potential habitat for long-term survival of Hog Deer in western Assam, given that it is the best protected grassland habitat in the region. To this end, we suggest regular monitoring of Hog Deer populations and habitat improvement to document population recovery with the minimisation of the extant threats, and the formulation of future management strategies.

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