POPULATION MONITORING AND COMMUNITY SUPPORT FOR HOG DEER (*AXIS PORCINUS*) CONSERVATION IN SHUKLAPHANTA NATIONAL PARK, NEPAL

by

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Abstract

Hog deer (*Axis porcinus*) are among the rarest animals in the world and are listed as "Endangered" on the International Union for Conservation of Nature's Red List of Threatened Species. Protected areas in Nepal are home to large and stable populations of hog deer relative to other parts of hog deer range, but changes in predator abundance, human activities, and climate change could alter hog deer abundance. Reliable and efficient methods to assess hog deer population trends are therefore essential to monitor changes over time. Combined with data on population numbers, support from local communities towards hog deer conservation is important in identifying key threats and developing appropriate conservation strategies. Accordingly, this research integrated natural and social sciences to evaluate density estimation methods and community support for hog deer conservation within Shuklaphanta National Park (SNP), Nepal.

Distance sampling along line transects is a common and relatively simple approach used to monitor hog deer populations in Nepal. Recent advances in technology, however, have enabled alternative approaches using data from remote-sensing cameras. Knowledge of the effectiveness of these two approaches could inform future monitoring efforts. Accordingly, I compared two methods for estimating the density of hog deer: distance sampling along line transects (n=17) and a random encounter model (REM) applied to data from remote-sensing cameras (n = 30). The density estimate produced by distance sampling (33.58 ± 8.48 individuals per km²) was more than double the estimate produced using the REM (12.95 ± 0.04 individuals per km²). Of the two methods, the estimate from the REM was more aligned with previous estimates of hog deer density. In addition, camera surveys facilitated the collection of data on multiple species, behaviour, and habitat use compared with line transects. However, despite requiring almost same

amount of time for data collection, camera surveys proved to be more costly. These findings highlight the need for a comparison of these density estimation methods with established techniques such as mark-recapture or block counts, coupled with expanded survey efforts to assess the accuracy of estimates.

To assess community support for hog deer conservation, I worked with research assistants to interview residents (n=30) from municipalities in the buffer zone surrounding SNP. Interview participants were knowledgeable about deer as a species group, but half of participants did not distinguish hog deer from other deer species. Most participants expressed positive attitudes towards hog deer conservation, especially in the context of promoting the local tourism economy around wildlife viewing. Participants explained that crop damage from deer has been largely mitigated by current management practices, such as fencing, but that additional fencing would further reduce conflicts. My findings revealed opportunities for collaboration between park managers and communities within the buffer zone, particularly around the development of the wildlife tourism industry and the design of management approaches such as fencing. Combined, my research provides guidance for future research and education efforts targeted at hog deer conservation.

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Glossary

AIC	Akaike Information Criterion
BNP	Bardia National Park
CAD	Canadian Dollar
CARE	Cooperative for Assistance and Relief Everywhere
CITES	Convention on International Trade in Endangered Species
CNP	Chitwan National Park
DNPWC	Department of National Park and Wildlife Conservation
EDD	Effective Detection Distance
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
Km^2	Square Kilometers
Mm	Millimeter
NPWC	National Park and Wildlife Conservation
NTNC	National Trust for Nature Conservation
NPR	Nepalese Rupee
REM	Random Encounter Model
SNP	Shuklaphanta National Park
UNBC	University of Northern British Columbia
WWF	World Wildlife Fund
^{o}C	Degree Celsius

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Chapter 1: Introduction

1.1 Background

Dramatic and on-going declines in biodiversity in the past 50 years highlight the need for more effective conservation actions to halt and reverse decreased population numbers (WWF, 2024). Conservation solutions, however, are particularly challenging in countries where dense human populations coincide with large numbers of endemic, rare or threatened species. For example, Nepal is a small country in South Asia that harbours disproportionately greater biodiversity relative to its size (Ghimire et al., 2021). Notably, Nepal is home to an estimated 4.2% of the world's mammal species despite covering less than 0.1% of the global landmass (Bist et al., 2021; Ghimire et al., 2021; Jnawali et al., 2011; Poudel et al., 2023). A lack of resources for conservation in Nepal combined with a reliance of local communities on natural resources, such as forest products, have resulted in the loss of habitat as well as high rates of human-wildlife conflicts (Baral et al., 2021; Gautam, 2006; Kandel et al., 2020; Kc et al., 2014; Waleligh & Jiao, 2017).

Despite these challenges, Nepal has established policies that have led to conservation successes, such as tripling the population of Bengal tigers (*Panthera tigris tigris*) nationally and increases in the population of one-horned rhinoceros (*Rhinoceros unicornis*) (Allendorf et al., 2020; DNPWC & DFSC, 2022). Conservation policies that have facilitated these successes include data collection used for designing and monitoring conservation efforts. As a key example, the Government of Nepal has been documenting mammalian fauna since the mid-1950s (Bist et al., 2021). More recently, the Government of Nepal introduced legal measures to protect wildlife, including the National Parks and Wildlife Conservation (NPWC) Act of 1973 and the National

Parks and Wildlife Conservation Regulations of 1974 (Aryal et al., 2021; Ghimire et al., 2021; Thapa, 2015). These measures led to the establishment of national parks, wildlife reserves, and conservation areas across the country. For example, the creation of Chitwan National Park (CNP) in 1973 marked a new era for habitat protection and wildlife conservation in Nepal (Bhattarai et al., 2017).

1.2 Protected Areas in Nepal

Today, Nepal's protected areas cover 23% of the country's total land area (DNPWC 2018). A protected area is defined as "a geographical space, recognized, dedicated, and managed through legal or other effective means to achieve the long-term conservation of nature, along with associated ecosystem services and cultural values" (Dudley et al., 2010).The protected areas of Nepal consist of 12 national parks, one wildlife reserve, one hunting reserve, six conservation areas, and 13 buffer zones (DNPWC, 2018). Each type of protected area serves a different purpose. A national park is designated for the conservation, management, and development of the natural environment, wildlife, plants, and landscapes (Aryal et al., 2021). Buffer zones are peripheral areas surrounding national parks and wildlife reserves that provide an additional layer of protection while offering benefits to local communities (Wells, 1992).

The concept of buffer zones in Nepal was developed following the success of community forestry, which is led by local communities (Bhusal, 2012). Buffer zones around national parks and wildlife reserves encourage local communities to become involved in conservation efforts, ensuring that communities share in the benefits accrued from protected areas (Campbell, 2008). Within the buffer zone, residents are permitted to engage in activities including agriculture, controlled grazing, forest resource collection, and ecotourism endeavors such as wildlife safaris, homestays, and community-based conservation under the condition that these practices do not harm the environment or wildlife (Aryal et al., 2021). Approximately 30% to 50% of the revenue from parks and wildlife reserves is used to fund conservation-related initiatives that benefit local communities in the buffer zones (Silwal et al., 2022). These initiatives include education programs to raise literacy and environmental awareness among youth and adults in collaboration with organizations such as World Wildlife Fund (WWF)/Nepal, Cooperative for Assistance and Relief Everywhere (CARE)/Nepal, National Trust for Nature Conservation (NTNC) and local government organizations (Bhusal, 2012).

1.3 Ungulate Conservation and Research

Despite strong conservation policies and a large network of protected areas, recent studies have highlighted biases in conservation efforts towards large, charismatic megafauna such as tigers and rhinoceros. By contrast, ungulates are relatively understudied despite their ecological, cultural, and economic importance (Poudel et al., 2023; Pascual-Rico et al., 2021). Specifically, wild ungulates play a critical role in maintaining terrestrial ecosystems by influencing plant communities and nutrient cycling. Grazing by ungulates can increase forage quality for herbivores due to richer soil and changes in plant phenology (Moe & Wegge, 2008). Ungulates also influence the density and distribution of large mammalian carnivores such as tigers and leopards (*Panthera pardus pardus*) (Karanth et al., 2004). For example, deer make up 75% of the diet of tigers across most of their range (Bhandari et al., 2017). The population size of predators is often tied to the abundance of ungulates, which form the bulk of their diet. Having abundant ungulate populations can also minimize tiger forays into human settlements (Baniya et al., 2017). Hence, promoting ungulate conservation can help reduce human-wildlife conflict (Bhandari et al., 2022).

Many ungulate species contribute to Nepal's ecotourism industry. Ecotourism provides an alternative livelihood strategy to agriculture for the people living adjacent to the protected areas

(Thapa, 2015). Tourists visiting national parks often come to observe species such as Bengal tigers, one-horned rhinoceros, swamp deer (*Rucervus duvaucelii*), spotted deer (*Axis axis*), and hog deer (*Axis porcinus*). Revenue provided through taxes and park fees by tourists contributes to conservation projects and local economies (Poudyal et al., 2020).

1.4 Hog Deer Conservation and Biology

Among 28 species of wild ungulates found in Nepal, hog deer is one of the least studied (Dinerstein, 1979). Hog deer, known as Laguna in Nepal, belong to the family *Cervidae* and are among the rarest wildlife species in the world (Arshad et al., 2012). Hog deer have experienced dramatic declines of at least 30% in recent decades due to habitat degradation, illegal hunting for meat, grassland burning, flooding, and the invasion of grassland by woodland plant species (Lamichhane et al., 2020; Odden et al., 2005). In Nepal, habitat loss and degradation have largely restricted hog deer to protected areas, such as Chitwan National Park (CNP), Bardia National Park (BNP), Banke National Park, Parsa National Park, and Shuklaphanta National Park, although hog deer spend some time on agricultural lands outside protected areas (Bhattarai & Kindlmann, 2013; Bhatta & Joshi, 2020 Lamichhane et al., 2020; Pokhrel & Thapa, 2008). The International Union for Conservation of Nature (IUCN) (2021) has listed hog deer as "Endangered" on the Red List of Threatened Species because of population declines and threats. Hog deer are also listed in Appendix III of the Convention on International Trade in Endangered Species (CITES).

Hog deer are a small species approximately 70 cm in height and 50 kg in weight and are considered a relative of spotted deer due to the white spots on their coats (Bhowmik & Chakraborty, 1999). Hog deer can be identified by their pelage color and morphological features (Dhungel & O'Gara, 1991), which include a yellowish-brown to brown and/or reddish-brown to dark-brown clay-colored coat, short legs, and a stocky body (Bhowmik, 2002; Poudyal et al., 2020). Females are smaller than males and lack antlers. Hog deer are primarily grazers that prefer young shoots of grasses but also feed on herbs, flowers, fruit, and sometimes browse (Dhungel & O'Gara, 1991). Hog deer mostly use grassland habitat in lowland areas (Odden et al., 2005). Breeding season for hog deer starts in July and continues through November with a major breeding peak in September and October. Hog deer typically occur in groups of 2–30 but are sometimes found solitary. When threatened, groups do not flee as a herd but scatter in different directions with their heads held low and their tails elevated, displaying the white underside. Social grouping varies throughout the year and between the sexes. The primary social group consists of females and fawns whereas adult males are typically solitary. Adult hinds are often seen with adult stags during the peak breeding season (Dhungel & O'Gara, 1991).

1.5 Shuklaphanta National Park

Of protected areas within Nepal where hog deer occur, Shuklaphanta National Park (SNP) is home to hundreds of hog deer, though it has fewer hog deer compared to Chitwan and Bardia National Parks (Odden et al., 2005; Poudyal et al., 2020: Wegge & Storras, 2008). SNP is located in the southern part of Far Western Nepal (Sadadev et al., 2023). The climate of SNP is tropical monsoon with three distinct seasons: winter (November–February), summer (March–June) and monsoon (July–October) with an average maximum temperature of 37ºC. Around 30% of the park's area is covered by grassland. Shuklaphanta is the largest grassland in lowlands of Nepal, spanning an area of 34 km^2 located to the south-west of the Bahuni River and south of the forest (ShNP, 2017).

In addition to the Park, a buffer zone was established around the Park, allowing local communities to use resources sustainably and receive benefits from tourism, thereby promoting community-based conservation (Bhusal, 2012). The buffer zone is covered primarily with agricultural land followed by forest, water bodies, and grasslands and encompasses seven municipalities, 38 wards, and 280 settlements that includes approximately 18,000 households (Poudyal et al., 2020). A relatively large number of ungulate species are found within SNP, including swamp deer, spotted deer, barking deer (*Muntiacus muntjak*), hog deer, sambar deer (*Rusa unicolor*), as well as large carnivores such as Bengal tigers and leopards. Population monitoring, however, is only done regularly for swamp deer, Bengal tiger, and one-horned rhinoceros (Shrestha & Pantha, 2018). I chose SNP for this study because of its rich biodiversity, substantial hog deer populations, and its pivotal role in the conservation framework of Nepal's Terai region. Moreover, wildlife-human conflict due to crop damage has been identified as an issue around SNP, but the extent to which hog deer play a role in the loss of crops is unclear (Bhatta & Joshi, 2020).

1.6 Monitoring and Research Needs for Hog Deer in Nepal

Past research on hog deer has occurred largely as part of monitoring programs targeted at other species, particularly tigers. Since 2009, nation-wide assessments of the status of tigers and their prey has been conducted every four years as part of tiger recovery efforts (DNPWC & DFSC, 2022). The larger tiger population (from 121 to 355 individuals) urgently needs more food and space to survive (Aryal et al., 2016). Accordingly, managers need a reliable method to estimate prey abundance.

In Nepal, remote-sensing cameras and spatial capture-recapture methods are used to estimate the density of tigers and distance sampling along line transects is used to estimate the density of ungulates, the primary prey of tiger (DNPWC & DFSC, 2022). Distance sampling is a relatively simple, quick approach that can provide density estimates using data collected by observing animals along transects (Buckland et al., 2005). Remote-sensing cameras, however, are a relatively new method for collecting occurrence data that can be used to estimate density of many species (Carbone et al., 2001; Jackson et al., 2006; Rowcliffe et al., 2008), including ungulates (Pfeffer et al., 2018). Until recently, density estimation using camera traps was restricted to animals with unique markings that allow for the identification of individuals followed by application of spatial capture-recapture models (Karanth et al., 2004). Recent modeling approaches, however, have been developed to estimate the density of species without unique markings by making assumptions about encounter rates between animals and stationary cameras (Howe et al., 2017; Moeller et al., 2018; Nakashima et al., 2018; Rowcliffe et al., 2008). These density estimation techniques probably differ in quality (i.e., accuracy and precision of estimates) and efficiency (i.e., cost and effort), but no comparisons have evaluated the differences between methods for hog deer. Such comparisons could inform future monitoring efforts for hog deer.

In addition to methods for assessing hog deer populations, understanding the attitudes and knowledge of local people towards hog deer will help conservation interventions succeed by producing effective conservation policies, actions, and outcomes. Several studies in Nepal have examined the knowledge, attitudes, and experiences of local communities toward wildlife, particularly tigers and leopards (Bhattacharjee et al., 2022; Carter et al., 2014; Dhungana et al., 2016, 2022; Lamichhane et al., 2018; Oli et al., 1994) or more generally to protected areas (Karanth & Nepal, 2012; Shahi et al., 2023). These studies have highlighted conflicts between ungulates and local communities over shared land use, leading to crop damage (Adhikari & Khadka, 2009; Bhatta & Joshi, 2020; Pokhrel & Thapa, 2008). More detailed knowledge of the role of hog deer in crop damage is important in understanding whether management interventions are needed to reduce human-wildlife conflict. In addition, local people might offer valuable suggestions about the effectiveness of existing and potential management strategies (Su et al., 2020).

1.7 Research Objectives and Thesis Organization

In this thesis, my goal was to contribute to hog deer conservation by informing methods for population monitoring and examining opportunities for community involvement in conservation efforts. My objectives were to 1) compare the estimates produced by and efficiency (i.e., cost and time) required to estimate hog deer density using distance sampling and camera traps combined with random encounter models; and 2) assess the knowledge and attitudes of people who live in the buffer zone surrounding SNP towards hog deer conservation. I addressed these objectives through a combination of field and social surveys.

This thesis is comprised of four chapters. After presenting introductory material in the first chapter, I included two data chapters that are structured as stand-alone manuscripts that I plan to modify for publication. In the second chapter titled “Distance sampling produces a greater density estimate than a random encounter model for hog deer”, I compared techniques for estimating the density of hog deer, specifically focusing on distance sampling and camera trapping combined with a random encounter model. In the third chapter, “Local knowledge highlights opportunities for collaboration towards deer conservation in Shuklaphanta National Park, Nepal”, I investigated the knowledge and attitudes of local people relative to the ecology and conservation of hog deer. Research assistants and I used semi-structured questionnaires to interview 30 people within two municipalities (Bhimdatta and Beldadi) within the buffer zone of SNP. In the final chapter, I summarized the key findings from the two data chapters, discussed limitations of the research, and provided recommendations for future research and management. Combined, my research provides guidance for future studies on population monitoring as well as education efforts targeted at hog deer conservation.

Chapter 2: Distance sampling produces a greater density estimate than a random encounter model for hog deer (*Axis porcinus*)

2.1 Introduction

Estimating population density is crucial for understanding and managing wildlife populations (Härkönen & Heikkilä, 1999). Obtaining accurate estimates of density, however, remains a challenge for researchers because wildlife populations often fluctuate in time and space due to seasonal changes, habitat preferences, migration, and other ecological factors (Nichols & Williams, 2006; Rowcliffe & Carbone, 2008; Williams et al., 2002). In addition, not all individuals in a population are equally detectable, especially in cases of cryptic species or complex habitats, leading to potential underestimation or overestimation of density (Buckland, et al., 2001). The design of the study, including the placement of transects or sampling locations, also influences the accuracy of density estimates with inadequate sampling coverage potentially resulting in biased outcomes (Buckland, et al., 2001).

There are various methods for estimating the density of wildlife populations, each with strengths and limitations. Distance sampling, for example, involves one or more observers walking, flying, or driving along transects, typically in a straight line, and recording the perpendicular distance from the transect line to each observed animal or object (e.g., dung piles or nests) (Buckland et al., 2005). For animals that are likely to move in response to an approaching observer, the sighting angle and radial distance to the animal can be recorded and used to calculate the perpendicular distance. A probability density function curve is then fit to the distance data and used to estimate the area surveyed. One of the key features of distance sampling is that the probability density function can be used to estimate the proportion of individuals or clusters of animals that were not detected during the survey. The number of detections is then adjusted for imperfect detection of animals or objects with increasing distances from the transect line (Buckland et al., 2005; Thomas et al., 2010).

The key attribute of distance sampling is that a large proportion of the target species may be undetected during surveys and accounted for by the probability density function under the assumptions that 1) animals are distributed independently of the survey transect; 2) animals on the survey transect are detected with certainty; 3) distance measurements are exact; and 4) animals are detected at their initial locations and not double counted (Buckland et al., 2005). Meeting these assumptions depends on the distribution and visibility of animals within the survey area as well as behavior of the animals and may be challenging if the species is relatively mobile, travels in groups or is difficult to observe or identify. Obtaining reliable density estimates from distance sampling also depends on the number of observations; a minimum of 60–80 detections are required while travelling along survey transects to obtain a smooth detection function (Buckland et al., 2004).

Camera traps are a relatively new method for collecting occurrence data that can be applied to density estimates for elusive, rare, cryptic, and nocturnal species (Carbone et al., 2001; Jackson et al., 2006; Rowcliffe et al., 2008) including ungulates (Pfeffer et al., 2018). Camera trapping can be cost-effective (Cutler & Swann, 1999), minimally disruptive to the environment (Silveira et al., 2003), non-invasive, and applicable in a variety of habitats and climatic conditions where other field methods are likely to fail (O'Brien et al., 2003; Silveira et al., 2003). Estimating density and abundance through camera trapping was initially restricted to adapted capture-recapture models tailored for species with identifiable individual markings, such as tigers (*Panthera tigiris tigris*) (Karanth, 1995). Many species lack such distinct markings, however, and consequently, capture-recapture models applied to camera images are not suitable for species such as ungulates without unique markings (Carbone et al., 2001). Several methods have been developed to estimate population numbers without individual recognition, including Time to Event Model (Moeller et al., 2018), Spatial Counts (Evans & Rittenhouse, 2018), Distance Sampling Based on Camera Traps (CT-DS; Howe et al., 2017), Random Encounter and Staying Time (REST; Nakashima et al., 2018), and Random Encounter Model (REM; Rowcliffe et al., 2008),.

Among these, the random encounter model (REM) has been tested extensively on wildlife such as black-tailed deer (*Odocoileus hemionus columbianus*) (Nickerson & Parks, 2019), moose (*Alces alces*) (Pfeffer et al., 2018), roe deer (*Capreolus capreolus*) (Palencia et al., 2021), pine marten (*Martes martes*) (Manzo et al., 2011), wild boar (*Sus scrofa*) (Hofmeester et al., 2017), Europen hare (*Lepus europaeus*) (Caravaggi et al., 2016), and hog deer (*Axis porcinus*) (van Berkel et al., 2022). Notably, REM has produced density estimates similar to methods such as drive counts along line transects (Palencia et al., 2021). The REM is based on the ideal gas model, which has been used by physicists for nearly 150 years to predict encounter rates of gas molecules (Hutchinson & Waser, 2007). The estimator for animal density is derived by modeling animal movements in relation to the detection zones of stationary cameras, taking into account encounter rates, average speed, group size, and effective detection distance (Rowcliffe et al., 2008). Importantly, REMs are not sensitive to the spacing of cameras relative to the size of animal home ranges (Rowcliffe et al., 2008). The minimum sample size for density estimates using REM is approximately 50 images per species, 20 camera locations, and less than 1000 camera trap days for common species and more than 1000 camera days for rare species (Rovero et al., 2013; Rowcliffe et al., 2008).

Simulations and empirical studies have revealed that the data used to estimate parameters can have large effects on density estimates resulting from REMs, specifically average speed and day range of animal movement (Rowcliffe et al., 2016). Initially, these parameters were measured by tracking individual trajectories through telemetry or by following habituated individuals. However, speed and day range estimates made directly from camera images resulted in improved estimates due to their accounting of tortuosity as part of movement paths. Moreover, estimates from camera images can be done in a cost-effective and non-invasive manner for a wide range of species. REMs operate under three primary assumptions: 1) animal movement is random; 2) detections represent independent interactions between cameras and animals; and 3) the population is closed.

Obtaining reliable density estimates is particularly important for hog deer and other endangered species whose populations are subject to rapid habit changes due to human activities and climate change. Among 28 species of wild ungulates found in Nepal, hog deer is one of the least studied (Dinerstein, 1979). Hog deer have experienced declines in recent decades as a result of habitat degradation, illegal hunting for meat, grassland burning, flooding, and the invasion of grassland by woodland plant species (Lamichhane et al., 2020; Odden et al., 2005). Hog deer, also known as Laguna in Nepal (Poudyal et al., 2020), belong to the family *Cervidae* (Arshad et al., 2012), are considered a relative of spotted deer (*Axis axis*) due to the presence of white spots on their coats, and are one of the rarest wildlife species in the world (Bhowmik & Chakraborty, 1999).

In Nepal, most conservation and management activities have been focused on securing and conserving charismatic megafauna such as one horned rhinoceros (*Rhinoceros unicornis*) and Bengal tiger (Bhattarai & Kindlmann, 2013). Lesser known mammals, such as hog deer, have received little attention. Since 2009, the Government of Nepal has been conducting nation-wide assessments of the status of tigers and their prey every four years. The tiger population in Nepal has had a three-fold increase since 2009 (121 to 355; DNPWC & DFSC, 2022). The increased tiger population needs more food and space to survive (Aryal et al., 2016). Consequently, managers need a reliable method to estimate the abundance of prey species. The Government of Nepal has been using camera traps and spatial capture-recapture methods to estimate the tiger density, whereas distance sampling along line transects and pellet count methods are often used to estimate the density of tiger prey, such as hog deer. Other researchers, however, have recommended pellet counts and camera traps combined with random encounter models (REM) as a more precise and accurate method to estimate the density of tiger prey (Palencia et al., 2021; van Berkel et al., 2022).

Given differences among methods, comparing the efficiency and reliability of density estimation methods is important for deciding which approach to apply. In this study, I compared methods for estimating the density of hog deer, specifically focusing on distance sampling and REM based on camera images. I provided a comparison of the cost, time requirements, and the estimates derived from each method during surveys in 2023 conducted in Shuklaphanta National Park (SNP), Nepal. This park was selected due to its ecological significance, substantial hog deer population, and its pivotal role in the conservation framework of Nepal's Terai region (Poudyal et al. 2020).

2.2 Methods

2.2.1 Study Area

The study was conducted in SNP (Latitude 28º45'47"- 29º02'52" N and Longitude 80º05'45"-80º21'43" E), located in the southern part of Kanchanpur District, Nepal (Figure 1). The park spans 305 km^2 and has an altitude ranging from 175–1300 m above sea level (Sadadev et al., 2023). The climate of SNP is tropical monsoon with three distinct seasons: winter (November–February), summer (March–June) and monsoon (July–October) with an average maximum temperature of 37ºC (Poudyal et al., 2020). Forest, grassland, and wetlands are the major habitat types in SNP (Poudyal et al., 2020). Approximately 60% of the park area is covered by forest, with Sal trees (*Shorea robusta*) being the dominant tree species. Other forest types include moist riverine forest and Khair-Sissoo forest (*Acacia catechu–Dalbergia sissoo*). Approximately 30% of the park's area is covered by floodplain grassland of the savanna type, characterized by a mix of tall and short grasses. Rivers, streams, lakes, and swamps form the major wetland networks. In addition to hog deer, SNP supports swamp deer (*Rucervus duvaucelii*), spotted deer (*Axis axis*), barking deer (*Muntiacus muntjak*), sambar deer (*Rusa unicolor*), and one-horned rhinoceros as well as large carnivores, including Bengal tigers and leopards (*Panthera pardus pardus*) (Shrestha & Pantha, 2018).

2.2.2 Field Survey Design

I overlaid a grid of 2- x 2-km cells across SNP. The cell size was based on the largest known home range (0.11–2.23 km^2) of hog deer in Asia (Dhungel & O'Gara, 1991). I randomly selected grid cells that covered grassland habitat for camera placement (n=30). A subset of grid cells with cameras (n=17) were selected for distance sampling along line transects conducted from the backs of elephants. Grid cells for distance sampling were selected based on accessibility from range posts where elephants were housed. At the time of the field surveys, park staff were conducting controlled forest fires to promote the regeneration of Sal tree seedlings and to produce the new palatable grass shoots. Consequently, the field surveys were conducted in grassland habitat to avoid burns in forested areas. Moreover, grassland tends to be the primary habitat used by hog deer (Dhungel & O'Gara, 1991). By focusing my survey in grassland habitats where hog deer were most likely to occur, I increased the efficiency of sampling; however, this design limited the interpretation of my density estimates to grassland portions of the park. In addition to burning Sal forest, park staff burn grassland areas each year to promote the regeneration of grasses. I conducted the distance surveys between March 12th and April 25th 2023, during the dry season and after most of the grasslands had been burned. The low height of vegetation following the grassland burns allowed for easy detection of hog deer during our field surveys. During the field surveys, hog deer were often found grazing on the young shoots of grasses in groups of 10–20 individuals (Dhungel & O'Gara, 1991). The primary social group consisted of females and fawns (Dhungel & O'Gara, 1991).

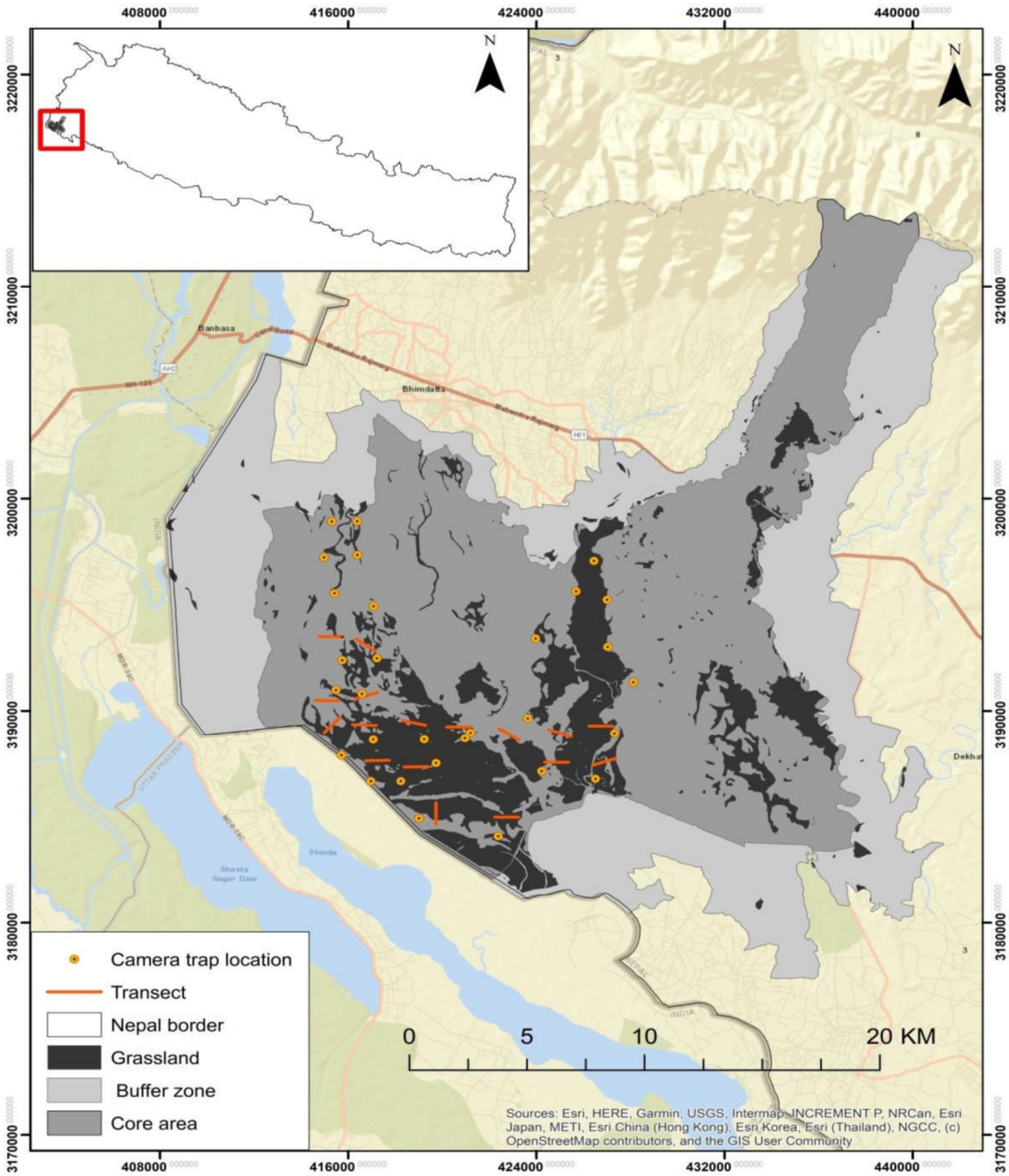

Figure 1: Locations of camera traps (n=30) and line transects (n=17) used to monitor hog deer (*Axis porcinus*) in the grassland of Shuklaphanta National Park, Nepal, in March and April, 2023. The inset shows the location of Shuklaphanta National Park within Nepal

2.2.3 Distance Sampling: I selected a random start point within the seventeen grid cells with a camera trap. I then followed a north-west direction within the grid cell along a straight line unless there were obstructions that required a change in direction. Each line transect was 1 km in length and was spaced 500–1000 m from other transects. The number of transects was limited by the availability of the elephants as well as constraints due to time, cost, and accessibility. Transects were conducted either in the morning (6:00 to 12:00) or evening (16:00 to 19:00), when hog deer were most active (Dhungel & O'Gara, 1991). The surveys were conducted by observers riding on elephants, which provide access to off-road terrain and protection from tigers and rhinoceros (Wegge & Storaas, 2009) (Figure 2). Each survey team consisted of one elephant driver, who was also an observer, and one or two additional observers seated on the elephant's back. The same transects were re-surveyed after a 7–day interval, covering a total surveyed distance of 34 km across all transects.

Observers recorded the sighting angle using a compass, the radial distance using a rangefinder, and location using a hand-held GPS for each individual or group of hog deer. Hog deer were differentiated from other species by their pelage color and morphological features (Dhungel & O'Gara, 1991), which included a yellowish-brown to brown and/or reddish-brown to dark-brown clay-colored coat, short legs, and a stocky body (Bhowmik, 2002; Poudyal et al., 2020). The underparts of hog deer are the same color as the back except for the underside of the tail that is white and they hold erect while running or disturbed. Females are smaller than males and lack antlers whereas fawns have white spots like those of spotted deer (Dhungel & O'Gara, 1991); however, it was not possible to differentiate among sex and age classes during the transects as hog deer often occurred in large groups of mixed sexes and ages.

Figure 2: Observers conducting line transects from the back of an elephant to estimate the density of hog deer (*Axis porcinus*) using distance sampling in the grassland of Shuklaphanta National Park, Nepal, in March and April, 2023.

2.2.4 Camera Trapping: I installed thirty motion-triggered cameras (Browning Dark OPS HD Pro Trail Cameras Birmingham, Alabama, USA) without bait or lure in randomly selected grid cells. Within grid cells, camera placement was constrained by available access points as well as terrain, vegetation, water bodies and other environmental considerations, resulting in uneven spacing between the cameras. Camera locations had a field of view of at least 10 m in front of the camera to facilitate detections of hog deer. If necessary, I pruned the vegetation in front of the camera to minimize false triggers and increase visibility. Random placement of cameras is an underlying assumption of REMs; therefore, I placed each camera facing north rather than focusing cameras on features such as trails or water holes. Each camera was secured 45 cm above the ground and programmed to take three photos per trigger day and night with a 1–s delay between triggers (Figure 3). I deployed cameras for 30 days and re-visited each camera every 10 days to check the batteries and remove images. In front of each camera, I placed five bamboo sticks in a straight line at fixed intervals of 2.5, 5, 7.5, 10, and 12.5 m. The sticks were all visible in the photos taken by the cameras and were used for measuring detection distance as part of the random encounter model

(Hofmeester et al., 2017; van Berkel et al., 2022). I attached red tape to the top of each marker to enhance their visibility in the photos.

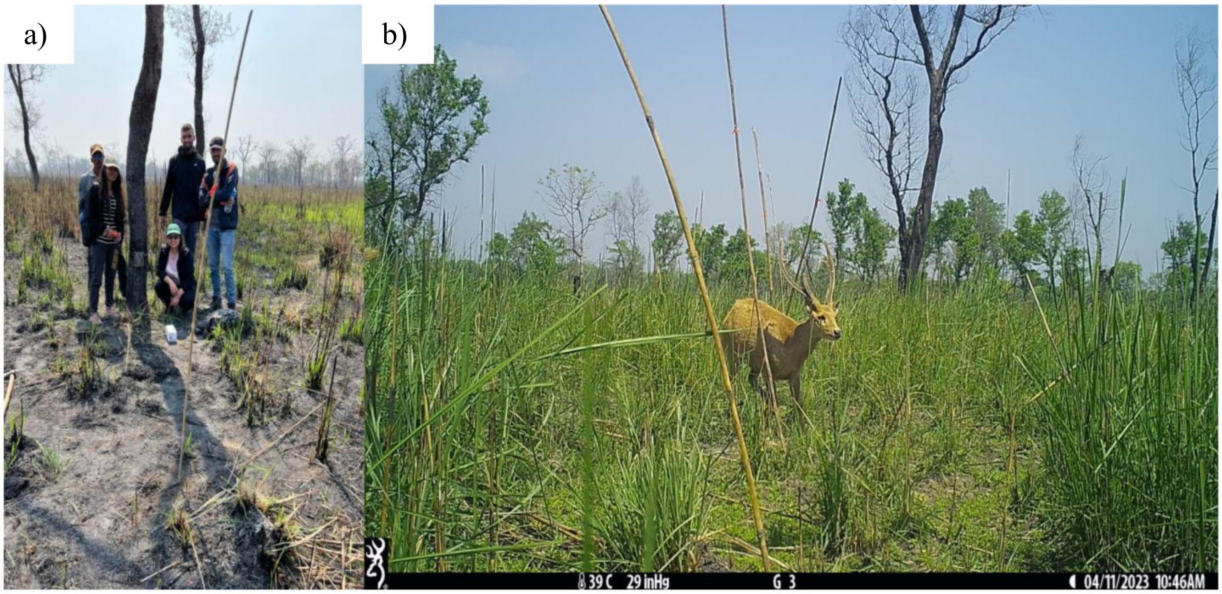

Figure 3: a) Researchers set up one of 30 cameras used to estimate the density of hog deer (*Axis porcinus*) using a random encounter model in the grasslands of Shuklaphanta National Park, Nepal, in March and April, 2023. Five bamboo stick markers were placed at distances of 2.5, 5, 7.5, 10, and 12.5 m in front of each camera. Red tape was attached to the top of each marker to enhance the visibility of the markers in the photos. b) A hog deer crossing the midline of the field of view at one of the camera sites.

2.2.5 Data Analysis

2.2.5.1 Distance Sampling along Line Transects

I used the “Distance” package (Miller et al., 2019) in R 4.3.1 (R Core Team, 2024) to estimate the density of hog deer according to observations collected along 17 transects. Perpendicular distances between the observer and hog deer were derived from the radial distance measured in the field. I used histograms and Akaike Information Criteria (AIC) to compare the fit of four detection functions (uniform cosine, uniform polynomial, hazard normal hermite, and hazard rate cosine). I assessed model fit using a Cramér–von Mises goodness of fit test and a Q-Q plot (Buckland et al., 2015).

2.2.5.2 Random Encounter Model using Camera Data

I used a modified version of the REM to calculate hog deer density at the same 17 grid cells where I applied distance sampling. The original REM estimates density by making assumptions about encounter rates between the first photo of an animal entering the camera's field of view and the detection zones of cameras (Rowcliffe et al., 2008). The model estimates rates of contact between moving animals and stationary cameras based on the area within which contact with animals occurs (i.e., the camera detection zone). This method requires estimating the angle of approach taken by an animal into the camera detection zone and the distance from the camera at which an animal is first detected; these measurements were taken by visiting camera sites and making field measurements. The modified REM is derived from a model proposed by Rowcliffe et al. (2008), but simplified in that only animals that cross the midline of the field of view are considered when modeling encounter rates. This method allows for detection distances from cameras to be approximated from images without the need for field site visits, provided distance markers are placed in front of cameras that can be used to classify animal detections into distance categories. Moreover, the modified REM allows for the estimation of effective detection distance by fitting a distance sampling function to frequencies of distances at which hog deer are detected from the camera, which improves model estimates by accounting for observations that were missed due to sensors of the cameras (Hofmeester et al., 2017). For this modified REM version, each pass of the hog deer across the midline of the camera's field of view is considered as an independent event irrespective of the time interval between observations (Hofmeester et al., 2017).

The REM formula that I used for hog deer density estimation (D, in deer/km^2) was as follows:

$$D = \left(\frac{Y}{H} . \frac{\pi}{(v.r.2)}\right) * g$$

where Y was the number of independent events of hog deer that crossed the midline of the field of view of a camera; π represents a mathematical constant i.e. 3.1415 ; H was the total number of camera days across all cameras; *v* was the estimated average speed of individuals over the period of a day averaged across all individuals that crossed the midline of the field of view (day range in km/day); r was the effective detection distance–the average distance (km) at which the number of animals detected further away from a camera equals the number of animals missed nearer by based on the probability detection function fit to distance data (Hofmeester et al., 2017); and *g* was the average group size derived from number of individuals observed in independent sequences of camera images where hog deer crossed the midline of the field of view.

To estimate parameters for the REM, I first identified sequences of photos where hog deer moved across the field of view of a camera. Next, I extracted metadata (i.e., time the image was taken and image length and width in pixels) from each photo using Exiftool (exiftool.org). I then calculated the distance moved between successive images by estimating the x and y coordinates of the left hoof of each animal. I estimated the y-coordinate in metres based on the bamboo stick markers placed in front of the camera and derived the x-coordinate from the image (Figure 4).

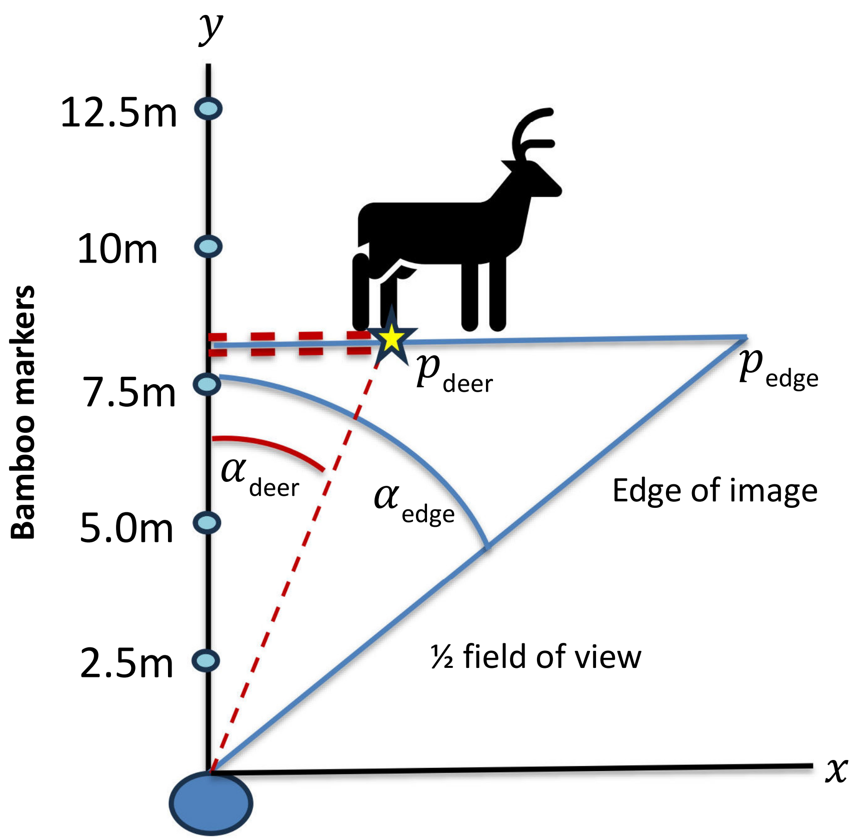

Figure 4: Method used to estimate the position of hog deer (*Axis porcinus*) traveling across the field of view of a stationary remote camera in Shuklaphanta National Park, Nepal. The x and y coordinates were estimated based on the position of the left hind foot of each animal, represented by the yellow star. The y-coordinate was determined based on the position of the animal relative to the bamboo stick markers placed at intervals of 2.5, 5, 7.5, 10, or 12.5 m from the camera. The x-coordinate was calculated based on the observation that the edges of the image are at the edge of the field of view of the camera; therefore, any point on the edge of the image, regardless of y, is at a fixed angle from the midline (i.e., half the field of view). The angle of the deer from the camera was calculated as $\alpha_{\text{deer}} = \frac{p\text{deer}}{p\text{edge}} \alpha_{\text{edge}}$, where $p$deer is the x-coordinate of the left hind foot read from the image in pixels, p_{edge} is the edge of the image in pixels, and α_{edge} is one half the field of view of the camera, provided in the camera manual. The x-coordinate of the deer (in metres) was calculated as $xdeer = y \tan \alpha deer$.

I estimated the speed of travel (metres/second) of each deer by calculating the Euclidean distance between the coordinates in two successive images, summing distances across photos in a sequence of images, and dividing by the time elapsed between the first and last image in a sequence. If there were two deer in a sequence of images, I made separate estimates of speed for each animal. Finally, I averaged the estimated speed across all sequences of images where hog deer moved across the midline of the field of view.

Subsequently, I calculated the daily distance travelled (*v)* as:

$$v = s*a$$

Where, v represented the daily distance travelled (km/day) by a typical hog deer, derived from the average speed (km/day) at which hog deer were observed moving in front of the cameras, as described above. The proportion of the day when a hog deer was active (*a*) was defined as the activity level, as described by Rowcliffe et al., (2016). I estimated the daily proportion of time spent active (*a*) for hog deer using the Activity package in R, which fits probability density functions to frequency data obtained from the capture events (Rowcliffe et al., 2014). The activity level (*a*) was estimated as the ratio of the area under the probability density function curve relative to the area of a rectangle that bounds the probability density function, representing the situation where an animal is active 100% of the time over a 24–hour period (Rowcliffe et al., 2014).

Effective detection distance is an important parameter in the REM for estimating encounter rates between moving animals and stationary camera traps. I estimated EDD (r) using distances obtained from the camera images and distance sampling. Distance sampling is a valuable approach in estimating EDD because animals passing closer to the camera are more likely to be detected than those that pass farther from the camera. A distance sampling model can account for imperfect detection of animals at greater distances from the camera, thereby improving estimates of EDD (Hofmeester et al., 2017; Laake et al., 2015). I classified the distance from the camera (in metres) at which each hog deer crossed the midline of the field of view of the camera into five distance intervals based on the positions of the bamboo stick markers (i.e., 0–2.5, 2.5–5, 5–7.5, 7.5–10 and 10–12.5). Next, I fit four detection probability models to the distance category data: a half normal model with cosine adjustment, a half normal model without adjustment, a hazard-rate model with cosine adjustment and a hazard-rate model without adjustment. The model that best fit the data was selected using Akaike's Information Criterion (AIC) values and by visually assessing the fit of the model to the data (Buckland et al., 2015).

I calculated group size (g) by averaging the number of deer recorded crossing the midline of the field of view for all observation events. I used non-parametric bootstrapping with resampling of the distance category data 1000 times to calculate a mean density estimate with 95% confidence intervals (Rowcliffe et al., 2008; van Berkel et al., 2022). Data were analyzed in R 4. 3.1 (R Core Team, 2024).

2.2.5.3 Cost Comparison

I calculated the costs and time required to conduct line transects for distance sampling and camera trapping for the REM. I estimated labour costs based on the number of personnel required to conduct field surveys at a rate of $20/hour per person. I also included the costs of paying elephant-driver teams to conduct distance sampling. I estimated the costs of data processing and analysis for both methods at $20/hour. I also included the rental cost associated with equipment used for distance sampling, including binoculars, rangefinders, and compasses. For cameras, I included the rental cost rather than the cost of purchasing new cameras, as I assumed that cameras could be used for multiple projects. All the costs were presented in Canadian dollars (CAD).

2.3 Results

2.3.1 Distance Sampling

A total of 65 hog deer were detected along the 34 line transects. No hog deer were detected on 9 of the 34 transects. The group size of hog deer ranged from 1–25 with an average of 2.7 individuals per group. All hog deer were detected between 0 and 44 m from the transect line. The probability of detecting hog deer close to the transect line (<10 m) was lower than the probability of detecting hog deer between 10–20 m from the transect line (Figure 5). Beyond 20 m, the probability of detecting hog deer decreased with greater distances from the transect line (Figure 5). All four detection probability functions had similar AIC scores (i.e., ΔAIC<4; Table 1). Although the uniform cosine and polynomial models had the lowest AIC scores, I selected the hazard rate cosine model for density estimation based on a visual examination of the fit of the curve to the frequency distribution of the data. Specifically, the hazard rate cosine model reflected the decrease in detection probability with greater distances from the transect line whereas the uniform cosine model produced a detection function with a flat line (Table 1; Figure 5). The Q-Q plot showed that the empirical distribution function for detection data generally followed the cumulative distribution function for the hazard rate cosine model, though there were some departures from the model (Appendix I). The goodness-of-fit test for the hazard rate cosine model indicated that the deviations were non-significant (Test statistic = 0.32, p–value = 0.12).

Using distance sampling, I estimated 33.58 ± 8.48 hog deer per km^2 (CV=0.25; 95% CI = 20.39–55.30). Left and right truncation did not improve the detection function and resulted in higher density estimates than without truncation. The AIC score of the model including group size was greater (AIC = 427.53) than the model without group size (AIC= 424.74), indicating that including group size in the model did not improve the model fit.

Table 1: Relative fit of four detection probability functions (uniform cosine, uniform polynomial, hazard normal hermit and hazard rate cosine) used to estimate density of hog deer (*Axis porcinus*) in the grasslands of Shuklaphanta National Park, Nepal, in March and April, 2023.

Detection probability function	**AIC**	**ΔAIC**	**Density (SE)**	**95% CI**
Uniform cosine	423.19	0	29.91 (6.59)	19.20–46.61
Uniform polynomial	423.19	0	29.91 (6.59)	19.20–46.61
Hazard normal hermite	424.74	1.55	33.00 (8.95)	19.38–56.19
Hazard rate cosine	**425.57**	**2.38**	**33.58 (8.48)**	**20.39–55.30**

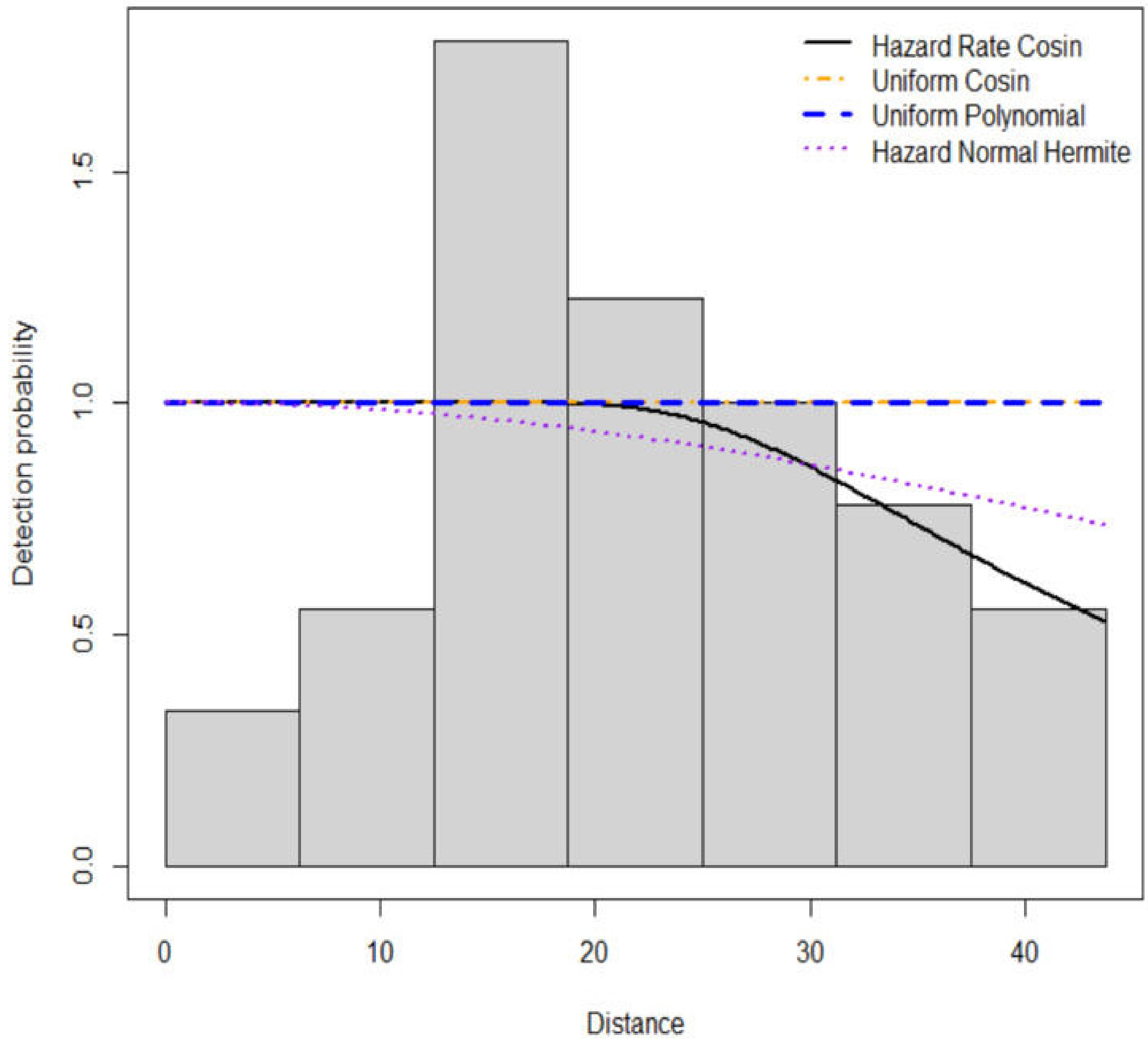

Figure 5: Fit of four detection models (uniform cosin, uniform polynomial, hazard normal hermite, and hazard rate cosine) to hog deer (*Axis porcinus*) data collected along line transects in Shuklaphanta National Park, Nepal, in March and April, 2023. The hazard rate cosine model reflected a decrease in detection probability with greater distances from the transect line whereas the uniform cosine model and the uniform polynomial model produced a detection function with a flat line.

2.3.2 Random Encounter Model Using Camera Trap Data

Over a period of 1170 camera trapping days from 30 cameras, there were 294 photographic encounters of hog deer that crossed the midline of a camera's field of view. The average daily speed of travel for hog deer was 4.805 km/day (SE=0.42) based on measurements of hog deer movement across sequential camera photos. The hazard rate model without adjustment provided the best fit to the distance interval measurements derived from camera images and was used to estimate effective detection distance (EDD; Table 2; Figure 6). The EDD was 0.00784 km. The REM provided an estimate of 12.95 ± 0.04 hog deer/km^2 (95% CI = 11.07–15.68; Table 3).

Table 2: Relative fit of four detection probability functions used to estimate effective detection (EDD) distance of hog deer (*Axis porcinus*) in grassland habitat of Shuklaphanta National Park, Nepal, in March and April, 2023, estimated with the marker transect method using single species, single-habitat point detection models. The models were ranked with AIC scores.

Detection probability function	**AIC**	**ΔAIC**	**EDD**
Hazard-rate function without adjustment	925.51	0	0.00784
Hazard-rate function with cosine adjustment	927.08	1.57	0.00768
Half- normal function with cosine adjustment	927.31	1.80	0.00726
Half- normal function without adjustment	929.21	3.70	0.00847

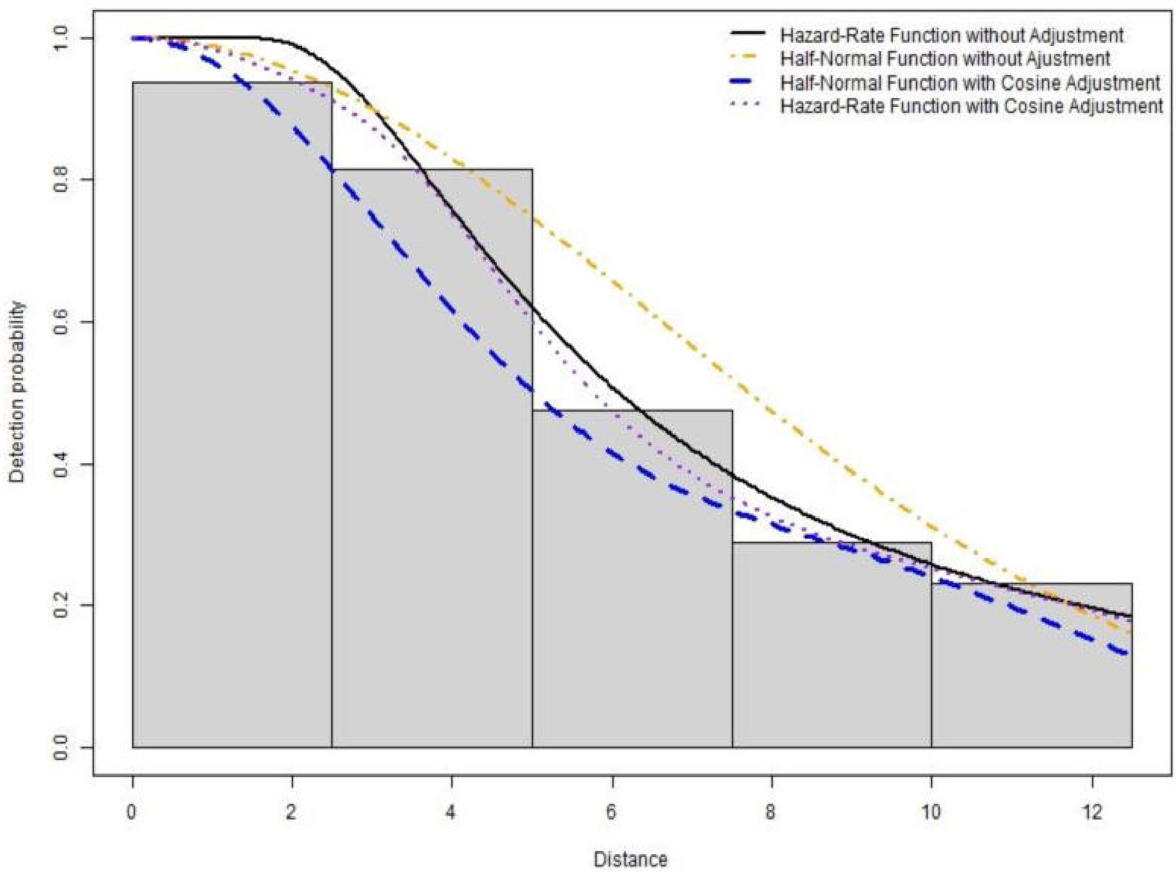

Figure 6: Fit of four detection models (hazard-rate function without adjustment, hazard-rate function with cosine adjustment, half-normal function with cosine adjustment, and half-normal function without adjustment) to hog deer (*Axis porcinus*) data collected at camera trap stations in Shuklaphanta National Park, Nepal, in March and April, 2023. The hazard-rate function without adjustment reflected a decrease in detection probability with greater distances from the markers and was used to estimate effective detection distance.

Table 3: Parameters used to estimate the density of hog deer (*Axis porcinus*) using a random encounter model in the grassland of the western sector of Shuklaphanta National Park, Nepal, in March and April, 2023.

Parameter	**Value (SE)**
Number of independent events of hog deer with midline crossing (Y)	294
Survey effort from all 30 cameras (24 h-trap days) (H)	1170
Average daily speed of travel for hog deer ($km24h^{-1}$) (v)	4.805 (0.42)
Effective detection distance (EDD) (km) (r)	0.00784 (0.732)
Average group size (g)	1.22
The proportion of the day that hog deer was active (a)	0.66 (0.087)

2.3.3 Cost Comparison of Density Estimation Methods: Distance Sampling and Camera Trapping

In total, the cost of data collection from distance sampling along 34 km of transects amounted to $6560 (i.e., $192/km), which included $900 for food and accommodation for 3 people (i.e., two technicians and the principal researcher) over 15 days at a rate of $20 per day plus $2720 in labour assuming each kilometer of transect took two hours by two people at $20/hour, $450 to hire an elephant and driver for 15 days at $30 per day, $90 for equipment rental for 15 days at $6/day and $2400 for data entry, processing and analysis by the principal researcher at $20 per hour for 120 days.

In total, the cost of data collection from 30 camera stations was $12,600 ($420/camera), including $2400 for food and accommodation for 4 people (i.e., three technicians and the principal researcher) over 30 days at a rate of $20 per day plus the costs of rental, purchase of batteries, labour, mileage and gas and image processing and analysis. For a single camera trap, the cost of rental was $40 ($1 per day x 40 days). Batteries cost $5 per camera. The labour cost per camera was $120, including 1 hour by 3 people to set up the cameras at $20 per hour ($60), 0.5 hours of work by 2 people to revisit the cameras three times at $20 per hour ($60). Mileage and gas for transportation to camera sites cost a $15 lump sum. Before analysis of camera data, I had to identify images with hog deer. The effort required to process images was directly related to the number of photographs taken. Image processing and analysis amounted to $4800 at $80 per day for 60 days for one person (Table 4).

Table 4: Effort and cost (CAD) to collect data by distance sampling along line transects and camera trapping combined with a random encounter model to estimate the population density of hog deer (*Axis porcinus*) in the grasslands of Shuklaphanta National Park, Nepal, in March and April, 2023

Method	Expense Item	Time (hours)	Cost/Unit ($)	Unit	Number Units	Total Cost
Distance Sampling (n=34)						
	Food and accommodation in field (3 people for 15 days)	NA	20	Day	45	900
	Equipment rental (binoculars, compass, rangefinder at $6/day for 15 days)	NA	6	Day	15	90
	Elephant-driver teams for 15 days at $30/day	68	30	Day	15	450
	Technician time for line transects (2 hours/transect at $40/hour for 2 people = $80/transect)	136	80	transect	34	2720
	Data entry, processing, and analysis by principal researcher ($20/hour for 120 hours)	120	20	Hour	120	2400
	Total	**324**				**6560**
Camera Trapping (n=30 sites visited 3 times)						
	Food and accommodation in field (4 people for 30 days)	NA	20	Day	120	2400
	Camera rental (30 cameras at $1/day)	NA	30	Day	40	1200
	Batteries	NA	5	camera	30	150
	Mileage to and from camera sites (3 visits at $5/visit for 30 cameras)	NA	15	Site	30	450
	Technician time for camera set-up (1 hour/site for 3 people)	30	60	Site	30	1800
	Technician time for camera revisits (3 revisits took 0.5 hours/revisit for 2 people at $20/hour)	45	20	Site	90	1800
	Image processing and analysis by principal researcher ($20/hour)	240	20	Hour	240	4800
	Total	**315**				**12600**

2.4 Discussion

Comparing methods for estimating population abundance and density is crucial for improving biologists' understanding and management of wildlife populations (Caravaggi et al., 2016). Here, I highlight substantial differences in density estimates for hog deer obtained through distance sampling compared with random encounter models. Specifically, estimates were more than twice as high using distance sampling (33.58 ± 8.48 individuals per km^2) compared with camera trapping (12.95 ± 0.04 individuals per km^2). These findings highlight the challenges associated with estimating density and the need for further studies replicated over space and time to refine methods for robust measures of density.

The density estimate of 33.58 ± 8.48 individuals per km^2 produced from distance sampling in my study is greater than previous estimates obtained by distance sampling for hog deer. For example, Karki et al. (2015) found a density of 21.6 ± 4.4 individuals per km^2 in SNP using distance sampling over 463 transects covering a total distance of 197.5 km. Similarly, a study by Adhikari & Thapa (2013) estimated hog deer density as 8.51 ± 4.47 (95% CI 3.13-23.10) individuals per km^2 in SNP over 26 transects covering 109.25 km. In Bardia National Park, Nepal, Wegge et al. (2018) estimated 16.5 ± 6.4 individuals per km^2 using distance sampling along 55 transects covering 132 km. Of note, my density estimate is lower than one reported by Odden et al., 2005, of 77.3 ± 56.4 individuals per km^2 in the floodplain association of Bardia National Park using counts in 46 habitat blocks during spring. Despite this exception, these comparative studies suggest that the distance sampling estimate obtained in this study may be unreasonably large.

One reason for the high density estimate from my distance sampling could be the lower survey effort (i.e., smaller sample size) compared with other studies. I surveyed a total length of

34 km whereas the other studies surveyed >100 km of transects. Less sampling effort would lead to more uncertainty in the density estimate. Furthermore, I observed a decrease in hog deer detections close to the transect line, which suggests hog deer moved away from the approaching observers. My finding that hog deer are sensitive to human disturbance agrees with findings of Lamichhane et al., (2020) in SNP, but contrasts with other studies showing that hog deer are tolerant of disturbances caused by domestic elephant mahouts and local villagers (Dhungel & O'Gara, 1991; Odden et al., 2005 ; Wegge & Storaas, 2009). Although the goodness of fit test did not suggest poor model fit, the movement of hog deer away from the transect violates one of the assumptions of distance sampling and may have contributed to an unrealistically high density estimate from our data.

Further differences between my distance sampling results and previous studies could relate to survey method and timing relative to grassland burning and cutting. For example, I conducted surveys after grassland burning from the backs of elephants to maximize the visibility of hog deer (Wegge & Storaas, 2009). In contrast, poor visibility before grassland burning, and walking transects on foot may have contributed to the lower density estimated by Adhikari & Thapa (2013). Nonetheless, my density estimate was greater than the estimate of Karki et al. (2015), who conducted surveys after grassland burning using elephants. Therefore, factors other than timing and methodology probably contribute to the high density estimate in my study. Notably, I surveyed in grassland areas only whereas other studies surveyed hog deer along transects spanning a variety of habitat types. Grasslands are the preferred habitat for hog deer, which would have led to a higher density than if I had surveyed all available habitat types. Finally, grassland management practices have changed since the previous studies were published that may have led to an increase in hog deer density. Specifically, SNP park staff have implemented alternate grassland burning and cutting, which increases the growth of high-quality forage for hog deer and may have led to recent increases in hog deer density. Alternate grassland burning and cutting is a management technique used to maintain and restore grasslands, particularly in protected areas in Nepal. This method involves burning or cutting patches in alternate cycles, often annually or biennially, which promotes the health of the grassland ecosystem by improving habitat quality for wildlife (Thapa et al., 2021; Sadadev et al., 2021)

My estimate of hog deer density using the random encounter model was 12.95 ± 0.04 individuals per km^2, which is less than half the estimate using distance sampling. Although random encounter models have not been applied previously to estimate hog deer density in Nepal, a study in Cambodia estimated the density of hog deer to be 41.8 individuals per km^2 using random encounter models (van Berkel et al., 2022). The greater density estimate in Cambodia could be due to ecological differences between study areas, such as a lack of predators. Alternatively, differences could be methodological. For example, random encounter models are highly sensitive to parameter estimates, particularly day range (Rowcliffe et al., 2016). Recent studies show that day range estimates derived from camera data enhance the precision and accuracy of density estimates compared with models that use telemetry data to estimate day range, probably because micro movements are included in estimates using camera data (Caravaggi et al., 2016; Pfeffer et al., 2018). The day range estimate of 4.805 km/day that I obtained from camera data was three times greater than the day range of 1.67 km/day estimated using telemetry data by Van Berkel et al. (2022). The difference in day range estimates could lead to substantially different density estimates.

In addition to producing substantially different density estimates, distance sampling and camera trapping differed in effort and cost. Distance sampling was logistically challenging because the elephants were used for several projects in SNP and scheduling time to fit in my sampling was difficult. In addition, the use of elephants limited sampling sites to areas within walking distance from the range posts to where elephants were housed. An advantage of distance sampling, however, is that the transects only need to be traversed once (although we chose to survey each transect twice). In contrast, cameras required a set-up visit, checks every 10 days to remove cards and change batteries, and a take-down visit. Another drawback of distance sampling compared with camera trapping is that collecting data on hog deer behavior was more challenging. Specifically, I was able to examine daily activity patterns of hog deer using camera images, which was not possible using data from distance sampling. A further challenge with distance sampling was that movement of hog deer away from the transect line made fitting a probability function to our data challenging. Despite these drawbacks, distance sampling required less effort (i.e., hours of labor) and cost compared with camera trapping. Notably, the repeat visits to each site combined with time required to process images led to the greater time required for camera trapping. Costs of camera rental and labor led to the greater costs.

2.5 Management Implications

Density estimates obtained from each method differed substantially and required different amounts of effort (i.e., time and cost), making it difficult to recommend a best method for future monitoring of hog deer in SNP. To further assess differences between methods, I recommend replicating density estimates using both methods over time and space to allow for a more robust comparison. Importantly, I recommend comparing these methods to a density estimation method that uses mark-recapture or stratified random block counts as these methods are well established for ungulate species and would allow for a comparison of (Koetke et al., 2024).

Of the two methods, the REM resulted in a density estimate that aligned more closely with expected estimates of hog deer density reported in the literature. The high cost of camera set up and revisits and the significant time required for data processing, however may make REM impractical for short-term studies or projects with limited funding (Zero et al., 2013). Moreover, REMs are sensitive to parameter estimation, specifically day range and effective detection distance. In future, sensitivity of the model to variation in parameters could be tested using simulations. In addition, a follow up study on density estimation using camera traps over multiple years looking at the repeatability of day-range estimates obtained through camera images is needed to understand the reliability of this method. Moreover, camera sensitivity (i.e., detection distance and detection angle) is also an important factor to consider for REMs, as sensitivity varies greatly with camera models and can affect density estimates (Rovero & Marshall, 2009). In this study, I only considered hog deer crossing midline of the field of view by having the detection angle set to 0. Future researchers could use both the detection distance and detection angle to density, potentially leading to an improved estimate of effective detection distance and effective detection angle (Palencia et al., 2021). If future research can refine parameter estimation approaches, REM could offer a promising alternative for estimating hog deer densities and could be particularly beneficial for long-term, multi-species and multi-season studies (Pfeffer et al., 2018). For example, in Nepal, REM models could be used to estimate the densities of tigers and their prey as part of periodic assessments conducted every four years.

My distance sampling findings highlight the challenges associated with this method for estimating hog deer densities due to the issue of animals moving away from the transect line, which violates one of the assumptions of distance sampling. To address this problem, future researchers and park staff in SNP could test whether surveys on foot reduce the displacement of hog deer compared with surveys on elephants. Furthermore, an expanded survey effort with a larger number of transects sampled in different habitat types over multiple years and seasons would help determine whether hog deer density in SNP can be reliably estimated using distance sampling.

Chapter 3: Local knowledge and positive attitudes highlight opportunities for collaboration towards deer conservation in Shuklaphanta National Park, Nepal

3.1 Introduction

Habitat change combined with a growing human population in recent decades has led to increased human-wildlife conflicts in many countries, including Nepal (Bhattacharjee et al., 2022). Addressing these conflicts often requires collaboration between communities and staff in centralized government agencies. For example, conservation interventions that involve local people and draw upon local knowledge are often more successful in addressing local environmental challenges, human-wildlife conflict, and ecosystem dynamics than those imposed by centralized, state-led governments (Karki & Adhikari, 2015; Malmer et al., 2015). In Nepal, buffer zones established around protected areas are one approach that has facilitated collaborations between communities and government agencies (Bhusal, 2012; Silwal et al., 2022). Buffer zones were implemented under the National Park and Wildlife Conservation Act of 1973 (4^{th} Amendment) and its Regulation of 1974 as areas where local people can participate in activities that support their livelihoods, such as livestock grazing. At the same time, there are restrictions on certain activities within buffer zones, such as hunting, that protect wildlife and other natural resources (Bhusal, 2012). Refining conservation approaches within these buffer zones requires feedback and understanding between local people and government officials and may require interweaving multiple knowledge systems (Budhathoki, 2004).

Recognizing the strengths of different knowledge systems is important for collaborations that aim to implement conservation actions. Three broad categories of knowledge systems include Western-based Scientific Knowledge, Indigenous Knowledge, and Local Knowledge, although each of these categories encompass diverse types of knowledge. Western-based scientific knowledge typically follows the scientific method and emphasizes objectivity, quantitative measurements, and the development of universal theories and models (Kadykalo et al., 2021). In contrast, Indigenous Knowledge encompasses deep-rooted cultural, spiritual, and ecological wisdom passed down through generations, often emphasizing interconnectedness with nature (Gadgil et al., 1993). Local knowledge reflects the experiences and practical understandings of communities that interact with their environments (Brook & McLachlan, 2008; Partasasmita et al., 2016). These knowledge systems are distinct but can complement one another by providing a more holistic approach to addressing complex environmental issues such as biodiversity and wildlife conservation, resource management, and climate change (Schmidt & Stricker, 2010; Weiss et al., 2013).

Surveys of local knowledge and attitudes are one method that can be used to mobilize information between government officials and community members. Local knowledge is developed by rural communities through learning and observation (Kadykalo et al., 2021; Su et al., 2020). Community members with local knowledge can contribute to conservation through citizen science, such as by monitoring population trends, providing insights into the habitat requirements of endangered species, and providing input on effective conservation strategies (Braga-Pereira et al., 2024; Gandiwa, 2012; Silwal et al., 2022). Understanding local knowledge about wildlife has helped educational programs that empowered communities to protect local wildlife and reduce human-wildlife conflict (Bhattarai et al., 2019; Bhuju et al., 2003; Carter et al., 2014; Hanson et al., 2019).

In addition to local knowledge, understanding the attitudes of community members towards conservation issues is fundamental to gaining local support and ensuring the long-term success of conservation initiatives (Bennett, 2016; Redpath et al., 2013). Attitudes encompass the positive or negative assessment of objects or topics and are composed of two primary components: cognitive (beliefs) and affective (feelings) that predict human behavior towards something, such as the presence of wildlife in their vicinity (Glikman et al., 2012; Lyamuya et al., 2014). Negative attitudes often result in the exploitation and harm of natural resources and wildlife, whereas positive attitudes foster conservation initiatives and support wildlife conservation efforts (Hariohay et al., 2018). Understanding the attitudes of people towards conservation issues can help identify the relative support towards different conservation interventions and generate enthusiasm among local people towards conservation issues. Moreover, evaluating peoples' attitudes can help understand associations between personal experiences with wildlife and public support for environmental policies and management actions (Stromer et al., 2019).

Several studies in Nepal have examined the knowledge and attitudes of local communities toward wildlife. Most of these studies focused on species that posed threats to human lives, such as tigers (*Panthera tigris*) and leopards (*Panthera pardus*) (Carter et al., 2014; Dhungana et al., 2016, 2022; Lamichhane et al., 2018; Oli et al., 1994) or species that damaged crops and property, such as wild boars (*Sus scrofa*) and elephants (*Elephas maximus*) (Karanth & Nepal, 2012; Shahi et al., 2023). The knowledge and attitudes of communities towards smaller and more cryptic species, however, has been less studied. For example, hog deer (*Axis porcinus*) are a small deer species that have not been the primary focus of social surveys in Nepal despite being listed as 'Endangered' in nature and a crucial prey species for tigers (Dhungel & O'Gara, 1991). Previous research has included hog deer as part of multi-ungulate studies, often highlighting the conflicts between ungulates and local communities due to crop damage (Adhikari & Khadka, 2009; Bhatta & Joshi, 2020; Pokhrel & Thapa, 2008). More specific studies of hog deer, however, are needed to assess the extent of local knowledge towards this species, the role of hog deer in causing crop damage, as well as the attitudes of local people towards hog deer conservation.

I examined the knowledge and attitudes of community members living in the buffer zone surrounding Shuklaphanta National Park (SNP), Nepal, towards hog deer. Specifically, my objectives were to 1) examine local knowledge of and experiences with hog deer; 2) explore the attitudes of local people towards hog deer conservation; and 3) understand current and future management initiatives aimed at mitigating human-deer conflict. I addressed these objectives by conducting semi-structured interviews with residents of the buffer zone surrounding SNP. My findings will help inform future educational and conservation initiatives towards hog deer and other deer species.

3.2 Methods

3.2.1 Study Area

Interviews were conducted in two municipalities (Bhimdatta and Beldadi) that were situated within buffer zones surrounding SNP, Nepal (Figure 7).

Figure 7: Municipalities (Bhimdatta and Beldadi) in the buffer zone of Shuklaphanta National Park, Nepal, where 30 people were interviewed about their local knowledge of hog deer (*Axis porcinus*) in October–November of 2023. The inset shows the location of Shuklaphanta National Park in the southwest corner of Nepal.

The Park is located in the southern part of Kanchanpur District in Far-Western Nepal with coordinates ranging from 28º45’47”–29º02’52” N latitude and 80º05’45”–80º21’43” E longitude. Covering an area of 305 km^2, the Park spans an elevation of 175 to 1300 meters above sea level (Sadadev et al., 2023). The Park’s major habitat types include forest, grassland, wetlands, and cultivated lands (Poudyal et al., 2020). Approximately 60% of SNP is forested, with Sal (*Shorea robusta*) being the dominant tree species. Other forest types include moist riverine forest and Khair-Sissoo forest (*Acacia catechu-Dalbergia sissoo*). As part of broader conservation efforts, the Park was originally established as Shuklaphanta Wildlife Reserve in 1976 to protect the largest herd of swamp deer (*Rucervus duvauceli duvauceli*) in Nepal. Ungulates that inhabit the park include spotted deer (*Axis axis*), barking deer (*Muntiacus muntjak*), sambar deer (*Rusa unicolor*), hog deer, blue bull (*Boselaphus tragocamelus*) and wild boar. Large predators include Bengal tigers and leopards (Poudyal et al., 2020). In 2017, SNP was designated a national park. (Bhatta & Joshi, 2020).

In 2004, a buffer zone was established around SNP, expanding the protected area by an additional 243.5 km^2. The purpose of the buffer zone was to involve local communities in conservation efforts while supporting their subsistence needs (Poudyal et al., 2020). Within the buffer zone, residents are permitted to engage in agriculture, controlled grazing of livestock and ecotourism (e.g., wildlife safaris, homestays, and community-based conservation), all under the condition that these practices do not harm the environment or wildlife (Aryal et al., 2021). Park staff monitor activities within the park and buffer zone and impose fines for illegal activities such as killing wildlife, cutting trees, overharvesting non-timber forest products. People within the buffer zone of SNP often experience challenges with wildlife such as tigers, leopards, wild boars, Asian elephants (*Elephas maximus*), and deer (*Axis axis*), which damage agricultural fields, threaten livestock, and occasionally result in human casualties (Bhatta & Joshi, 2020). To mitigate these issues, the national park has erected barbed-wire fencing around parts of the buffer zone over the last 10–15 years and has introduced compensation programs for wildlife such as Asian elephants, tigers, leopards, and wild boar for losses to life and property (Pant et al., 2023; Shahi et al., 2022).

The buffer zone of SNP encompasses five urban municipalities—Bedkot, Belauri, Bhimdatta, Mahakali, and Shuklaphanta—and two rural municipalities—Beldadi and Laljhadi (Pant et al., 2023). I selected Bhimdatta and Beldadi for this study because people from these municipalities often interact with wildlife (Bhatta & Joshi, 2020) and the local economy is tied to tourism and wildlife viewing in both municipalities (Bhimdatta, 2023; Beldadi, 2023). Therefore, I assumed participants from these municipalities would be knowledgeable about deer and would be involved in wildlife conservation. The municipality of Bhimdatta, previously known as Mahendranagar, serves as the administrative headquarters of Kanchanpur district situated in the north-west part of the park and ranks as the ninth largest city in Nepal. Bhimdatta is approximately six kilometers from the Indian border and the Mahakali River (Bhimdatta, 2023). Bhimdatta covers an area of 171.34 km^2 with 30.46 km^2 of the total area falling within the buffer zone of SNP (Bohara, 2015; Poudyal et al., 2020). The major ethnic groups in Bhimdatta are Brahmin, Chhetri, Tharu, Bishwokarma, Kami, Damai, and Sarki (GoN, 2023). Most of the population is Hindu. Agriculture is the primary source of livelihood. Businesses and remittances from foreign employment provide other important sources of income (Bhatta & Joshi, 2020). Bhimdatta has a population of 122,320 people according to the 2021 Census of Nepal (GoN, 2023).

The municipality of Beldadi is more rural than Bhimdatta and covers a total area of 36.54 km^2, of which 24.28 km^2 falls within the buffer zone surrounding SNP (Beldadi, 2023; Poudyal et al., 2020). Beldadi is culturally, linguistically, and ethnically diverse (Beldadi, 2023). The largest ethnic group is Kshetri followed by Brahman and Tharu (GoN, 2023). The population of this municipality is largely Hindu. The primary source of income is agriculture with other sources including livestock farming, tourism, and business (GoN, 2023). Beldadi has a population of 21,888 people, according to the 2021 Nepal Census (GoN, 2023).

3.2.2 Participants and Recruitment

This research was approved by the University of Northern British Columbia's Research Ethics Board (File no: 6009128). Participants were selected using purposive and snowball sampling methods (Valerio et al., 2016). Initially, we identified a few participants who were at least 18 years old and lived within 1 km of the park boundary. These participants referred others who also met the requirements. My decision to focus on participants who live within 1 km of the park boundary was based on the assumption that people living closer to the park would have more frequent encounters with wildlife compared with those living farther away (Mackenzie & Ahabyona, 2012). This snowball sampling approach was efficient in reaching participants with knowledge about wildlife conservation, however the approach would also bias results of the study towards participants whose livelihoods are tied to wildlife viewing.

3.2.3 Research Positionality and Data Collection

I acknowledge that the study design, questions, and interpretation of data from this research were influenced by my worldview and previous experience (Manohar et al., 2017). As a citizen of Nepal, I was born and raised in a Nepalese community. My familiarity with Nepalese culture and the geography and ecology of SNP and its buffer zone from my previous research experiences may have influenced the way I formulated survey questions and interpreted results, potentially leading to biases in the data presented herein. These biases included cultural bias, confirmation bias, and personal connection bias. Cultural bias could lead to misinterpretation of local knowledge and attitudes by assuming a shared understanding of participant responses based on my own cultural lens, potentially overlooking nuances of their unique experiences. Confirmation bias (i.e., bias due to prior knowledge) might cause me to prioritize data that aligned with existing literature and expectations, often limiting the scope of the analysis. Lastly, personal connection bias might make me overemphasize the challenges to highlight the conservation needs for local people. To address these biases, I reflected on ways by which my past experiences might influence survey questions and data interpretation (Corlett & Mavin, 2018). This reflexive practice helped me view my findings in a broader context beyond my personal experiences and limited bias introduced during data processing and interpretation. Nonetheless, I acknowledge that my personal experiences and knowledge may have influenced the interpretation of data presented here.

I worked closely with two research assistants to conduct interviews. The research assistants were paid for their time using research funding from the Rufford Foundation. Both research assistants are considered collaborators and will be authors in any publication resulting from this research. One of the research assistants is from a community near the study area whereas the other assistant is from Western Nepal. The research assistants had completed undergraduate degrees in forestry and had previous experience doing interviews with local communities. I mentored both research assistants in following our Research Ethics Protocol and in conducting interviews. Throughout the interview process in October–November of 2023, I kept in regular contact with the research assistants to discuss the data collection process. The research assistants pre-tested the questionnaire with five people to identify confusing language (Grimm, 2010). We discussed findings from the pre-testing and decided to simplify the language and change the order of some questions after pre-testing but did not change any of the questions.

A total of 30 interviews (15 in each buffer zone) were conducted in Nepali upon obtaining verbal consent from each participant. Research assistants requested verbal consent from participants due to variability in literacy rates; some participants might have been uncomfortable reading and signing documents (Appendix II; Bhattacharjee et al., 2022). The research assistants read out loud in Nepali a pre-approved consent script to participants before starting an interview (Appendix II). The script outlined the research objectives, funding sources, and the nature of the questions to be asked. In addition, the script explained study procedures to retain anonymity, store and analyze data, and share research findings. Interviews proceeded only after participants consented to the terms described in the script. Each participant was assigned a unique identification number to retain anonymity of audio recordings, written notes, and transcripts of interviews. Therefore, there was no way of linking interviews to participants once the interview was complete.

A semi-structured questionnaire was used for the interviews, including Likert-scale[1], open-ended questions, and closed-ended questions (Table 5). The Likert-scale questions included five options ranging from "strongly disagree" to "strongly agree". The open-ended questions provided the research assistants with the flexibility to adapt the interview questions based on interactions during the interview (Karanth, 2007). The questionnaire was organized into three parts (see Appendix II). First, the research assistants asked participants about socio-demographic characteristics, including gender, age, occupation, ethnic group, religion, livestock holdings and agricultural crops. Next, participants responded to questions about their knowledge and experience with hog deer and other deer species. As part of this section, each participant was shown photographs of hog deer, swamp deer, sambar deer, barking deer, spotted deer, and wild boar to assess their familiarity with hog deer and other local ungulates (Figure 8; Table 6). They were able to identify wild boar from the photographs but most of the participants could not identify hog deer and other deer species thus the research assistants used the term “deer” (Nepali name “chital”) in subsequent questions to refer collectively to hog deer and other deer species. Finally, participants responded to questions about their attitudes and opinions around conservation and management of deer. This section included Likert-scale questions asking participants to rank their opinions about deer sightings and conservation. In addition, participants were asked open-ended questions about compensation programs and fencing as strategies to mitigate damage caused by deer and about the significance of deer to the local tourism economy. To avoid placing participants in legal trouble, no questions were asked about illegal hunting or illegal activities associated with hog deer or other

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[1] A Likert scale is an ordinal scale, typically with 5 or 7 points, that respondents use to indicate the extent to which they agree or disagree with a statement (Sullivan & Artino, 2013)

deer species. At the end of the interview, participants received an honorarium of 100 Nepalese Rupees (equivalent to $1 CAD) for their time. The interview was recorded using an audio device, supplemented by hand-written notes. Each interview lasted approximately 45 minutes to one hour. The principal researcher transcribed all recordings verbatim. Hand-written notes were typed into a Microsoft Excel spreadsheet for further analysis.

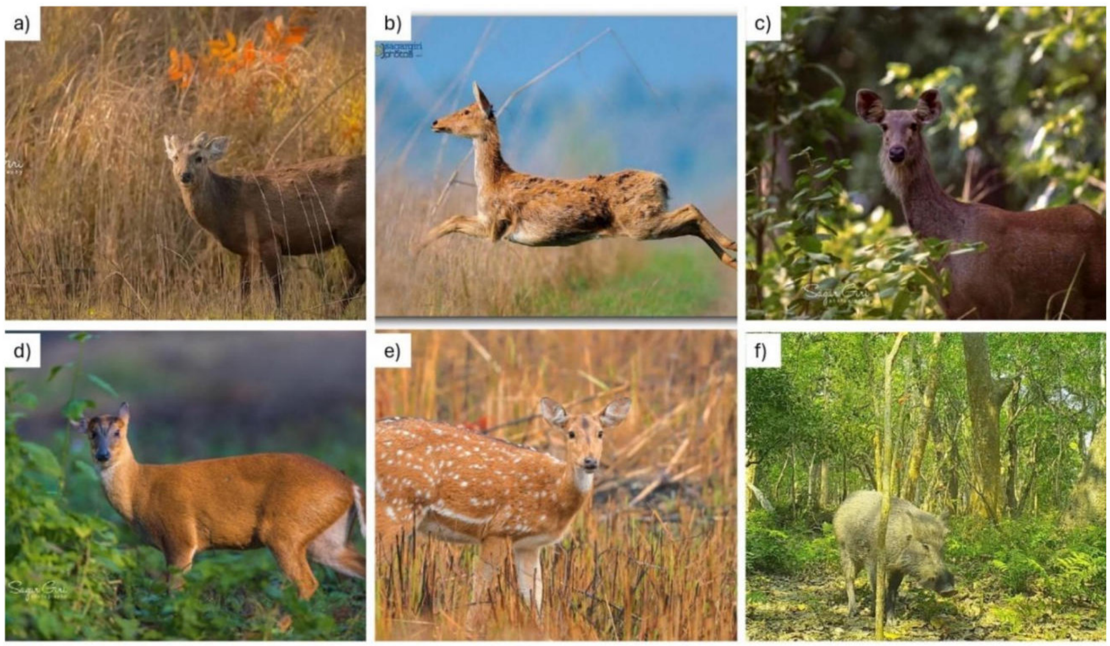

Figure 8: Photographs of a) hog deer (*Axis porcinus*), b) swamp deer (*Rucervus duvauceli duvauceli*), c) sambar deer (*Rusa unicolor*), d) barking deer (*Muntiacus muntjak*), e) spotted deer (*Axis axis*), and f) wild boar (*Sus scrofa*). The photos were taken by Sagar Giri, Wildlife Photographer, and used with permission. These photos are similar to the photos shown to participants (n=30) during interviews conducted in the municipalities of Bhimdatta and Beldadi within the buffer zone of Shuklaphanta National Park, Nepal, in October–November of 2023.

Table 5: Interview questions grouped according to a-priori themes, along with the type of question (i.e. open-ended, closed-ended, or Likert scale) used to interview 30 participants residing within 1 km of the boundary of Shuklaphanta National Park, Nepal. Interviews were conducted in two municipalities (Bhimdatta and Beldadi) within a buffer zone surrounding the Park.

Interview Questions	Question type
Socio-demographic characteristics	
What are your age, gender, occupation, annual income, ethnicity and education?	Open-ended
What animals do you have?	Closed-ended
What animal products do you sell?	Closed-ended
What agricultural crops do you grow?	Closed-ended
Knowledge and experience with hog deer and other deer species	
Out of the species shown in the photographs, which ones can you identify? Which ones have you seen?	Open-ended
What do you call hog deer (or deer) in your local language?	Open-ended
Do you usually see hog deer (or deer) alone or in groups	Open-ended
In what ways do hog deer (or deer) influence your farm, agricultural land or livestock?	Open-ended
Can you describe any changes in hog deer or (deer) abundance over time? What might be the reason behind any changes in hog deer (or deer) sightings over time?	Open-ended
To what degree do you like seeing hog deer (or deer) in your locality?	Likert scale
How do you respond when you see hog deer (or deer) on farmland?	Open-ended
Conservation and management of hog deer (or deer)	
To what degree do you feel that conservation of hog deer (or deer) is important?	Likert scale
What does conservation of hog deer (or deer) mean to you?	Open-ended
Do you get any compensation from the park or buffer zone management committee when hog deer (or deer) damage crops or livestock? If yes, what amount? How easy is it to access the compensation program? If no, do you think a compensation program or subsidizing fencing would be helpful to address potential conflicts between people and hog deer or (deer)?	Open-ended
Can you describe the role of hog deer (or deer) in local tourism economy?	Open-ended
What actions could be used to conserve hog deer (or deer)	Open-ended

Table 6: Defining features of six ungulate species found in Shuklaphanta National Park and the municipalities of Bhimdatta and Beldadi, Nepal, where interviews were conducted with 30 participants in October–November, 2023.

Species	Body size (kg)	Antlers	Pelt	Defining features from other species
Hog deer *(Axis porcinus*)	30–50	Males only	Juveniles are brown with white spots; adults do not have spots	Small body size with a long body and relatively short legs; underside of tail is white; hold tail erect when running
Spotted deer (*Axis axis*)	70–90	Males only	Golden to reddish brown; covered in white spots in juveniles and adults	Slender body with a spotted coat
Swamp deer (*Rucervus duvaucelii*)	210–260	Males only	Yellowish brown to dark brown; no white spots	Long legs with short head and broad ears; hair around the neck forms a shaggy mane in winter; mostly found in swamps
Sambar deer (*Rusa unicolor*)	225–320	Males only	brown and shaggy;no white spots	Largest deer in Nepal; adult males have a three-tined antler; nocturnal and solitary
Barking deer (*Muntiacus muntjack*)	13–35	Males only	Brown; no white spots	Shy and solitary; Small body size and short antlers; produce dog-like barking call when alarmed
Wild boar (*Sus scrofa*)	68–100	No antlers	Dark brown or black; no white spots	Feral pigs, not deer species; bulky, thick-set bodies, long, cartilaginous snouts

3.2.4 Data Analysis

I summarized responses to the Likert scale questions by calculating the percentage of participants who agreed or disagreed with each statement. I conducted a thematic analysis of the

Nepali transcripts using NVivo 14 plus. I used an inductive approach to identify themes within the data through an iterative analytic process. This approach involves reading and interpreting raw contextual data to develop themes by deriving codes from the data itself (Kekeya, 2016). First, I read transcripts to generate codes that described the information provided by participants in the interviews. I generated a new code each time I noted a different topic related to local knowledge or attitudes towards hog deer. In total, I generated 98 codes. I then grouped the codes into three themes: 1) local knowledge and experience; 2) attitudes towards deer; and 3) attitudes towards deer conservation. The thematic analysis allowed me to integrate information from multiple questions when summarizing responses.

3.3 Results

The study included 30 participants (15 from each buffer zone) who took part in interviews (Table 7). Fourteen of the 30 participants self-identified as female and 16 as male. The largest proportion of the participants were adults between 35–55 years old (19/30), followed by young adults between 18–35 years old (6/30), and seniors ≥56 yrs old (5/30). The majority of participants were employed in agriculture (23/30). Other occupations reported by participants included business, student, labour, foreign employment, and retired. Sixty-seven percent (20/30) of participants reported an annual income of 0–2500 CAD, 23% (7/30) reported an income of 2500–5000 CAD, and 7% (2/30) reported an income greater than 5000 CAD. Participants belonged to 5 ethnicities, including Dalit (9/30), Brahmin (8/30), Chhetri (8/30), Thakuri (4/30), and Tharu (1). Forty-seven percent (14/30) of participants had completed elementary education, 20% (6/30) had completed secondary school, 17% (5/30) had not completed formal education, and 7% (2/30) possessed a university degree. The majority of participants kept goats (25/30) as livestock followed by calves (16/30), cows (13/30), buffalo (13/30), bulls (6/30), and poultry (6/30). Three percent (2/30) of the participants had no livestock. Forty-six percent (13/30) of the participants sell meat followed by milk (29%; 8/30) to run their household. The majority of participants grow paddy (25/30) followed by wheat (24/30), mustard (23/30), vegetables (23/30), potato (21/30), peas (11/30), sugarcane (7/30), maize (6/30) and barley (4/30). These crops are grown either on agricultural land or in the residential gardens of participants. Three percent of participants (4/30) did not grow any agricultural crops.

Table 7: Socio-demographic characteristics of 30 participants who were interviewed about hog deer (*Axis porcinus*) conservation in and around Shuklaphanta National Park, Nepal, in October and November of 2023. Participants were residents of the Bhimdatta and Beldadi municipalities within the buffer zone surrounding the Park.

Attribute	Category	Number	Percentage (%)
Gender	Male	16	53
	Female	14	47
Age	18–35 yrs	6	20
	35–55 yrs	19	63
	≥56 yrs	5	17
Occupation	Agriculture	23	77
	Business	2	7
	Student	1	3
	Labour	1	3
	Foreign Employment	1	3
	Retired	2	7
Annual Income (Canadian Dollars)	0–2500	20	67
	2500–5000	7	23
	5000 –7500	1	4
	7500 –10000	1	3
	Not Reported	1	3
Ethnicity	Dalit	9	27
	Chhetri	8	27
	Brahmin	8	3

	Thakuri	4	30
	Tharu	1	13
Education	No formal education	5	17
	Elementary	14	46
	High School	6	20
	University Degree	2	7
	Not Reported	3	10
Livestock holdings	Goat	25	31
	Calf	16	20
	Cow	13	16
	Buffalo	13	16
	Bull	6	7
	Poultry	6	7
	None	2	3
	Honey bees	0	0
	Pig	0	0
	Sheep	0	0
Livestock products	Meat	13	46
	Milk	8	29
	Ghee	4	14
	Curd	2	7
	Honey	1	4
	Eggs	0	0
	Cheese	0	0
	Bees wax	0	0
Agricultural crops	Paddy	25	17
	Wheat	24	16
	Mustard	23	16
	Vegetables	23	15
	Potato	21	14
	Peas	11	7
	Sugarcane	7	5
	Maize	6	4
	Barley	4	3
	None	4	3
	Millet	0	0
	Jute	0	0
	Cotton	0	0

3.3.1 Local Knowledge and Experience

3.3.1.1 Deer Identification and Local Names

Only five of 30 participants identified hog deer species when shown images of six local species of ungulates (Figure 9). Similarly, few participants identified sambar (6/30) and barking deer (7/30) as species. By contrast, most participants identified spotted deer (20/30), swamp deer (23/30), and wild boar (29/30) in photographs. After the interviewer described differences among ungulate species in the photos, 17 participants recalled in-situ observations of hog deer (Figure 9). Participants were also more likely to recall in-situ observations of other ungulate species after the defining features of each species were explained by the interviewer.

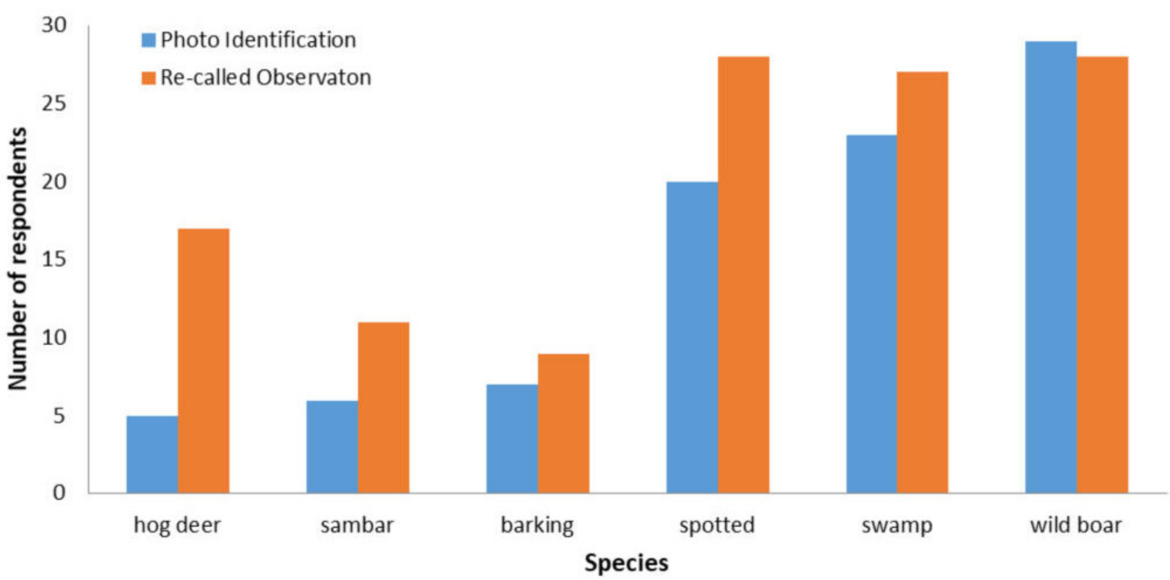

Figure 9: Number of interview participants who correctly identified ungulate species from photographs of each species (blue bars) compared with the number of interview participants who recalled observations of each species after species were identified by the interviewer (red bars). Interviews were conducted with 30 participants who resided in the Bhimdatta and Beldadi municipalities within the buffer zone of Shuklaphanta National Park, Nepal, in October–November of 2023. Ungulate species included hog deer (*Axis porcinus*), swamp deer (*Rucervus duvauceli*

duvauceli), sambar deer (*Rusa unicolor*), barking deer (*Muntiacus muntjak*), spotted deer (*Axis axis*), and wild boar (*Sus scrofa*).

Participants identified different types of deer based on morphology and behaviour, but classifications did not always align with western scientific taxonomy. For example, Participant 5 explained "We call deer with antlers 'chital' and deer with big antlers 'swamp deer'". From a western scientific taxonomic perspective, 'chital' (spotted deer in English) and swamp deer have antlers that are similar in size but swamp deer can be differentiated by their larger body size (Table 6). Similarly, Participant 13 explained "We call deer with antlers 'dadaiya' and 'chital' to those without antlers", possibly referring to males with antlers compared with females without antlers or to times of the year when deer do not have antlers. Rather than differentiating among types of deer, Participant 21 explained "We call all deer 'chital' in our local language". Some participants grouped deer according to the presence or absence of white dots on the pelt. For example, Participant 6 referred to hog deer as a baby chital (English name—spotted deer[2]) because juvenile hog deer have white spots on the pelt similar to spotted deer:- "Oh! this is the baby of chital and it is small in size." Participant 3 emphasized that hog deer is a fast runner by saying "It runs very fast. Other deer look back and stand still but this deer runs whenever we look at it." The observation about running ability is consistent with the name 'hog deer', which refers to the species' tendency to run through the forest like hogs and to duck under obstacles, unlike most other deer that leap over obstacles. Some participants had not observed hog deer previously. For example, Participant 7 mentioned "Does this species of deer live in our national park? I have not seen it." Collectively,

[2] In Nepal, most of the people refer to deer as spotted deer (Nepali name – Chital).

these statements reveal that participants classify deer based on morphology and behaviour drawn from local knowledge and observations.

As further examples of local knowledge, participants used 10 different names to refer to deer in Nepali, including chital, padiya, kakad, mirga, padhuwa, gunta, thar, laguna, sauja, and dadaiya. Participants also described observations of deer social interactions and behaviour; 84% of participants reported seeing deer in groups rather than solitary, with group sizes ranging from 5 to 60. For example, “I have seen this in a group while coming to drink water in river (Participant 2)”; “I saw them in groups, sometimes in a group of 10–15 and sometimes in a group of 50–60 (Participant 26)”; and “this deer used to be in groups and sometimes in a group of 10–12. I have always seen this deer running here and there and have never seen it alone (Participant 9)”. This indicates that local people possess some knowledge about deer, as they refer this species by providing various local names and can describe changes in its social interactions over the years.

3.3.1.2 Changes in Deer Sightings Over Time

Twenty-one of 30 participants (70%) reported seeing deer more often within the national park in recent years but less often near human settlements and agricultural lands. For example, Participant 29 mentioned “In the past, deer were more abundant in our area, but due to fencing, their population has decreased locally. However, their numbers have increased within the national park compared to before. Previously, deer would venture onto roads, where people would hunt them. Nowadays, such actions lead to legal consequences, with offenders facing imprisonment for harming deer.” Another participant reported seeing deer more often near human settlements in recent years and attributed the increase to hunting regulations that prevent people from killing deer along with conservation efforts that have led to increased deer numbers. Specifically, the participant explained “Before whenever deer came here, people would kill and eat them but nowadays if they kill them, they go to jail. Also, due to more conservation efforts and fencing, their number has increased.” Interestingly, one of 30 participants (3%) observed an increase in deer sightings near human settlements during the rainy season specifically and suggested that deer come to agricultural areas to avoid mosquitoes and leeches: “I don’t know about change. But when it’s cold and raining heavily, they come out of the national park to enjoy the sunshine and to get away from mosquitoes and leeches (Participant 26)”. Ten percent (3/30) of participants reported no noticeable change in deer abundance and suggested that predation from leopards and tigers within the national park prevent increases in the deer population. For example, “I've observed the same numbers over time. In the past, it was like this, and now it's the same. Sure, there might have been an increase, but any growth in population is offset by leopard predation (Participant 13)”. Seventeen percent (5/30) of the participants reported seeing deer less often due to increased disturbances by vehicles and altered habitat. “We see deer less frequently nowadays (Participant 19)”.

3.3.2 Attitudes Towards Deer Encounters

Ninety-seven percent (29/30) of participants expressed positive attitudes, either liking or strongly liking the presence of deer in their locality. Despite positive attitudes overall, some participants expressed frustration with the damage done by deer to their crops. For example, Participant 10 mentioned “I hate when deer damage my crops; otherwise, it’s worth seeing them in the locality”. Similarly, Participant 26 explained “I like to see this animal as they are our national animals however sometime if they do a lot of damage I don’t like them and I become angry (Participant 26)”. Nevertheless, 3% (1/30) participants disliked deer sightings, primarily due to concerns about deer causing damage to vegetables and crops: “I strongly dislike deer as they continuously eat my crops and vegetables (Participant 1)”. Overall, these comments demonstrate that people view deer positively unless deer cause damage to their crops.

Most participants mentioned that deer caused substantial damage to their crops before fencing was built around the park to reduce human-wildlife conflict. Since these measures were established, participants explained that other species, specifically elephants, wild boar, and nilgai cause more damage than deer. For example, Participant 24 said: *“*Of course, deer influence our farm and agricultural land. In the past, they came often and we had to stay on the farm in bamboo machan to maintain watch over farmlands but now due to fencing, their number has decreased and they sometimes come however other animals such as wild boar, nilgai, and wild elephant come often these days and damage crops and vegetables.*”* As another example, Participant 7 also described greater problems with wild boar, nilgai, and wild elephant compared with deer: “Chital (deer) come, eat vegetables and run away but it’s the wild boar that give us a hard time by destroying our crops. Sometimes, Chital (deer) get trapped in fences and die. I haven't seen any hog deer around here. Instead, we mostly see nilgai, wild boars, and wild elephants.*”* None of the participants reported deer affecting their livestock.

3.3.2.1 Local Management of Deer on Agricultural Land

Participants explained that deer typically run away when they see people. If deer do not run away, most participants chase them into the forest by making noise, lighting fires, or using dogs. For example, Participant 12 said: “We watch over our agricultural land from a small hut. When deer come, we bang on dishes to chase them away; however, they come again.” Some participants call the park authority if the deer start eating their crops. Participant 13 mentioned “if deer come to the village, we call the park authority." Other participants do not chase deer away from agricultural land because they believe deer have a right to use these areas: "We don't chase them away. What is the benefit of chasing them away? For instance, we are living in our home. They also like to live in their home. This national park is their home. I wish good things for them (Participant 1)". Overall, the comments from participants reveal that people use different methods to chase deer back to the national park after seeing them on agricultural land. Furthermore, the comments reflect the generally positive attitudes of participants towards deer and the beliefs that every being has the right to survive and live in its own home. For instance, people like deer to be in the national park (forest) but not on their farmland.

3.3.3 Attitudes Towards Deer Conservation

When asked about deer conservation, 97% (29/30) of participants agreed or strongly agreed that deer conservation is important. Moreover, all participants (n=30) identified deer conservation as important for expansion of the local tourism economy. The participants explained that deer attract tourists, which provide opportunities for jobs in the hospitality, transportation, and retail sectors. For example, Participant 26 explained "For me, conservation of deer increases the number of tourists. Tourists cannot enter the national park without tickets. Tickets cost around $10–50 CAD and they stay in hotels and homestays, need vehicles and local guides to enter and watch around the national park, buy souvenirs, which ultimately help to increase the economy of the nation". As another example, Participant 21 mentioned that "visitors will come to see the animals and the national park. This will increase the popularity of the local place." Furthermore, Participant 29 said "if visitors come, they will need tourist guides to show them different areas of the national park, which will create job opportunities for local people. They will take beautiful pictures of the animals. They will also get chance to talk with local people and learn about their culture and tradition. From all these things, we also get benefitted".

In addition to benefits to the local tourism economy, participants highlighted the importance of deer to the national economy and global recognition of Nepal. For example, Participant 3 mentioned "Nepal is a poor country recognized all over the world for its national parks". This indicates people have an economic interest in deer in terms of enhancing tourist interest in the area. In addition to economic importance, some participants stressed that humans have a responsibility to conserve and protect deer for future generations, highlighting the extrinsic value of deer. For example, Participant 23 mentioned "Conservation of deer is a must for the next generation otherwise they will be only in history if not conserved". In contrast with the majority, one of 30 participants (3%) remained neutral towards hog deer conservation, explaining that "there are both positive and negative aspects. If the deer eat our crops, it's a disadvantage for us. However, if people come to see the area because of the deer, it's beneficial for us (Participant 5)."

3.3.3.1 Government Led Conservation Approaches

All participants (n=30) responded that there was no compensation program for damage caused by deer. For example, "there's no compensation program for deer. Similarly, the park doesn't offer compensation for damage caused by wild elephants or wild boars (Participant 3)". Rather than subsidies, participants identified fencing, boundary walls, and electric fencing as preferred strategies to protect crops. Participants explained that compensation amounts are typically inadequate to compensate for damage to crops and the process to receive compensation is lengthy. For example, Participant 10 explained "fencing helps to conserve the animals and protect our crops. So, fencing is good for us. Also, compensation amounts are low." Similarly, Participant 26 exclaimed "No, no! Instead of getting money as compensation, it's better for us to use fencing. This way, the deer can live in their own place, and we don't have to stay up all night worrying about them. Compensation doesn't give us enough money, and the process takes a long time. So, it's better to keep the deer away by putting up fences. Even if they do give us some money for the damage, it's usually not enough."

3.3.3.2 Future Conservation Practices

Participants offered a variety of suggestions about future conservation practices for deer. Five of the thirty participants (17%) suggested training and conservation campaigns to raise awareness of deer among residents of buffer zone. Other participants recommended watch towers (3%) or sirens (23%) to reduce damage by deer to agricultural lands. For example, "sirens for elephants and other animals should be given (Participant 3)". One of the thirty participants (3%) recommended building overpasses or underpasses to reduce deer mortality on roads and to provide artificial water sources to deer. Four participants (14%) recommended calling the park authority after seeing deer on agricultural land rather than chasing or killing them. For example, "If hog deer or deer come to our villages, we should not kill them, rather we should call the park authority, such as the game scout (Participant 28)".

Forty percent of participants mentioned that the government should protect deer habitat and implement strict regulations to reduce illegal hunting. For example, Participant 7 explained "There are few range posts. In some part of the park, the number of range posts should be increased." One of the 30 participants added that everyone needs to work together to conserve wildlife in the Park. For example, Participant 26 said "Government should do something so that we can also conserve the forest."

3.4 Discussion

This study explored the knowledge and attitudes of people residing in the buffer zone surrounding SNP towards deer conservation. Overall, this study found that participants had considerable local knowledge of deer species that could be applied towards conservation efforts. Half of participants did not differentiate hog deer as distinct from other deer species, suggesting that future conservation efforts could focus on raising awareness of the ecology and habitat requirements of hog deer. Participants expressed generally positive attitudes towards deer and deer conservation and identified increased fencing to prevent the movement of deer from SNP onto agricultural lands as a suitable approach to mitigate human-deer conflicts in this region. Moreover, participants highlighted the importance of deer conservation as part of the further development of tourism opportunities in the area. In this discussion, I have highlighted the community support for hog deer conservation and opportunities for collaboration between park managers and communities within the buffer zone, particularly around the development of the wildlife tourism industry and the design of management approaches such as fencing.

Interview participants represented diverse age classes, ethnicities, and religions. Previous studies have found that demographic factors such as age, education level, income, and livestock holdings shape people's views on wildlife (Dhungana et al., 2022; Mir et al., 2016; Shahi et al., 2022). For example, educated individuals tend to have more positive attitudes towards wildlife conservation (Karanth & Nepal, 2012; Mutanga et al., 2015) and are often better equipped to understand the role of protected areas in conservation and the ecosystem services they provide (Dewu & Røskaft, 2018). Similarly, wealthier people who directly benefit from the park also express positive attitudes towards conservation (Shahi et al., 2023). Demographics, including age and gender also play a role in creating positive attitudes, with younger individuals generally showing higher environmental concern than older individuals (Gifford & Sussman, 2012; Newmark et al., 1993) and men often exhibit more environmental knowledge than women (Gifford & Sussman, 2012). In addition, local residents who rely less on natural resources, live further from buffer zones, have fewer wildlife encounters, or are actively involved in managing protected areas are more likely to support wildlife conservation than counterparts (Karanth & Nepal, 2012; Shrestha & Alavalapati, 2006; Subedi et al., 2020; Olomí-Solà et al., 2012) . In contrast, those who experience conflicts with wildlife or park administration tend to hold negative attitudes (Shahi et al., 2023). Although my findings don't coincide with the above finding and also my study did not explore demographic differences among attitudes towards and knowledge of deer conservation, future research using a larger sample of the local population should investigate these associations.

Participants displayed varying abilities to identify hog deer as distinct from other deer species. Only five of 30 participants identified hog deer to species when shown photos; this finding could be due to challenges in identifying animals to species from static images, which may not convey important defining features, such as an animal's size and habitat. Over half of participants recalled in-situ sightings of hog deer after the interviewer identified hog deer. Participants who were familiar with hog deer shared behavioural and morphological observations of the species, including their small size, the presence of white spots on the pelt of some individuals, and ability to run quickly. These comments reveal that some participants were knowledgeable about hog deer specifically. Nonetheless, several participants commented that they had never seen a hog deer or lumped hog deer with other deer species. Collectively, these findings suggest that about half of participants lack knowledge of hog deer as a distinct species.

Compared with hog deer and barking deer, which are both relatively small in body size, more participants differentiated among larger ungulate species, including spotted deer, swamp deer, and wild boar. In addition to a larger body size, spotted deer, swamp deer, and wild boar may be more distinctive than hog deer due features such as the spotted pelt of spotted deer and body shape and horns of wild boar. People may also be more familiar with the larger species because they may be more tolerant to human activities and more likely than smaller ungulate species to cause crop damage, especially wild boar (Khanal & Singh, 2019; Pandey et al., 2016). Finally, spotted deer, swamp deer, and wild boar are generally more common than hog deer, so participants may be more likely to encounter them either in communities or within SNP (Khanal & Singh, 2019; Pandey et al., 2016; Poudyal et al., 2020). Most participants were unfamiliar with sambar, which is a large ungulate in south-east Asia but is relatively rare in SNP and may not be commonly observed (Hutchins et al., 2003; Jnawali et al., 2011; Poudyal et al., 2019; Poudyal et al., 2020).

Although some participants classified ungulate species differently from western scientific taxonomic classifications, many described local knowledge and experiences with ungulates. For example, participants referred to ungulates using ten different local names, including chital, kakad, mirga, and gunta. Many Indigenous communities across the globe use different names for different groups of animals, reflecting their unique local knowledge. For example, the Inuit in northern Canada use specific local names for different types of caribou, which reflect detailed observations of the animals' physical characteristics, behavior, seasonal movements, and habitat (Ljubicic et al., 2018). Farooq et al. (2021) found that fear of snakes is a key factor in assigning local names to different snake species. These names help local healers identify the species responsible for a snake-bite and assist in educating children about which snakes pose potential danger. Further research could explore the meaning of the different names used by interview participants in reference to deer in relation to observations of behaviour and ecology of different types of deer.

The majority (70%) of participants reported fewer recent sightings of deer on agricultural lands within their municipalities compared to the past. Participants attributed this change to fencing that reduces the movement of deer from SNP into surrounding communities. In addition, participants reported seeing deer more often within SNP in recent years, possibly due to enforcement of stricter regulations on hunting activities and habitat conservation efforts. Thirty percent of participants, however, reported either no change in the frequency of deer sightings or fewer sightings. Differences in opinion around deer sightings could reflect differences in the opportunities participants have to observe deer, such as the amount of time spent in agricultural areas and in SNP. I assumed that all participants living within 1 kilometer of the park boundary would have similar opportunities to observe deer; however, I did not ask participants about the amount of time they spent on the land, which would have an impact their responses. Another reason for differing opinions about deer sightings could relate to differences in participants' abilities to distinguish among deer species; if some participants treat multiple deer species as one, trends in observations of separate species could be missed. Local knowledge where local communities consistently monitor and report changes in wildlife populations such as elephants, leopards, spotted hyena and other vertebrates has proven to be an effective method, often yielding results comparable to those obtained through more quantitative techniques (Braga-Pereira et al., 2024; Gandiwa, 2012; Van Damme et al., 2015),. However, Ponce-Martins et al., 2022 reported some genera of animal species hard to identify regardless of the method used, including deer in the family.

My finding that residents living within 1 kilometer of the SNP boundary had positive attitudes towards deer aligns with studies that found positive attitudes towards deer and several other wildlife species in SNP and Chitwan National Park, Nepal (Dhungana et al., 2022; Bhatta & Joshi, 2020). Several factors probably foster positive attitudes towards deer in SNP. Although deer sometimes enter agricultural land and damage crops, they rarely harm people or livestock. Consequently, many people enjoy seeing deer on their agricultural land. In addition, people appreciate that deer are native to Nepal and contribute to the natural beauty of the national park (ShNP, 2017). Deer are also important for wildlife-based tourism, which has flourished in part due to the large population of swamp deer in SNP (ShNP, 2017). Tourism has boosted the local economy by supporting hotels and homestays and creating job opportunities in the hospitality sector. Cultural exchanges between visitors and locals have also strengthened community support for deer conservation, Thapa (2012) reported ecotourism as one of the meaningful sources of economic development and job creation for people living in and around protected areas. For example, the presence of national and international visitors in the Gandruk village of Pokhara, Nepal has encouraged Gurung people to preserve their culture, traditions, dresses, tools, songs, and dance (KC et al., 2015). Expansion of ecotourism in SNP has the potential to provide similar benefits to nearby communities.

Only one participant reported a negative attitude towards deer conservation (3%). Support for wildlife and conservation initiatives often diminishes when people's interests and livelihoods are threatened (Bhatta & Joshi, 2020; Hill, 1997). Repeated damage to crops by deer has compelled local people to stay overnight in bamboo machan to guard their fields (Karki et al., 2022; Neupane et al., 2014; Pudasaini et al., 2020). Furthermore, while the government provides compensation for human injury or death by tigers, leopards and elephants, livestock loss by tigers, leopards, snow leopards or bears, crop damage by elephants, wild boars, rhinos and property damage by elephant, there is no compensation scheme for crop damage by deer. Even if compensation for damage caused by deer were available, participants explained that based on their experiences with other compensation programs, the process for obtaining compensation is lengthy and cumbersome, and the compensation amounts are insufficient to cover the damage caused by wildlife. Shahi et al., (2022, 2023) similarly reported that the local people hesitate to report their losses made by wildlife species such as common leopard because the compensation process is time-consuming and complex and compensation amounts are inadequate to offset losses. Notably, compensation amounts provided by the government of Nepal are set at 10,000 Nepalese Rupees (CAD 100) to the victims of crop damage and 1,000,000 Nepalese Rupess (CAD 10,000) for human loss (Karki et al., 2022; MOFE,2013). Because of these small amounts, local people prefer fencing (regular or electric) or construction of a boundary wall made of bricks and cement around the park boundary rather than relying on compensation (Banikoi et al., 2017; Neupane et al., 2018; Shahi et al., 2022).

Participants provided insight into local management practices used to prevent crop damage by deer. In general, participants explained that deer often run away and therefore human interventions are not always required to prevent crop damage by deer. Some participants reported making noise, lighting fires, or using dogs to chase deer away from their crops, which indicates that traditional methods are effective in preventing damage by deer to agricultural land. The studies cited by Hussain et al. (2022); Neupane et al. (2014) and Pokharel & Aryal (2020) further support the effectiveness of low-cost, community-driven methods to manage deer and other wildlife such as black bear (Ursus americanus), snow leopard (Panthera uncia), common leopard (Panthera pardus), elephants, wild boar, and monkeys (Rhesus macaque). These findings imply that integrating traditional techniques with modern management practices, such as fencing, could be effective to address human-deer interactions in agricultural areas.

In addition to traditional management practices, participants recommended fencing as a preferred management approach to mitigate human-deer conflict. Participants explained that the barbed wire fencing that has been installed around SNP has reduced deer movement into agricultural land, but that the fencing has been less successful in deterring species such as monkeys, wild boars, wild elephants, and nilgai. These findings suggest that additional fencing, particularly electric fencing, could help further reduce human-wildlife conflicts around SNP. Electric fencing has proven to be both economically and socially beneficial in reducing the movement of wild animals into agricultural areas and the damage they cause to crops and livestock (Sapkota et al., 2014). For example, in Bahundangi Village Development Committee of Jhapa district, Nepal, the estimated annual economic loss per household in 2014 before fencing was 103 USD (crop = 95 USD and property = 8 USD). However, after the installation of solar-powered electric fencing, crop damage was reduced by 93% and property damage by 96 % (Neupane et al., 2018).

3.5 Management Implications

Although local people have considerable knowledge and experience regarding ungulate species, future research should explore the extent of each individual's experience with these species. In the case of hog deer, understanding their role in the ecosystem can foster local conservation efforts in monitoring population declines and understanding habitat requirements, especially in areas where they frequently visit (Adhikari & Thapa, 2013; Odden et al., 2005). Some participants did not distinguish hog deer from other ungulates, which suggests that non-western taxonomic classifications should be examined further. The difficulty local people face in identifying different deer species through photographs underscores the need for comprehensive and interactive classes and courses on deer species identification so that local people could share their thoughts and knowledge at the same time as learning about different species (Meadows, 2011). Informal education focusing on posters and brochures of different deer species would be useful in creating awareness among local people (Budhathoki et al., 2018). If possible, education could be incorporated as part of promoting tourism by training local people and building their capacity as nature guides or natural history interpreter would add another boon to the local community (Baral & Heinen, 2007). A more collaborative approach such as round-table discussions or workshop-style approach that allows people to learn about hog deer and also share their knowledge and experiences in a way that promotes collaboration would also be helpful (Aryal et al., 2012). A follow up study on names of deer species is highly recommended to understand the reason and story behind those names. Additionally, it will be important to assess the use of fencing as a management tool and address challenges related to compensation programs.

Chapter 4: Conclusion

4.1 Research Summary

Conservation efforts in Nepal have led to positive outcomes for wildlife species, including tigers (*Panthera tigris tigris*) and one-horned rhinoceros (*Rhinoceros unicornis*). Lesser-known species, such as hog deer, have received less attention despite concerns about their population status globally. Moreover, recent increases in tigers could influence the abundance of some prey species, including hog deer. Accordingly, my thesis examined methods for assessing hog deer abundance to inform future monitoring efforts. In addition, I assessed the knowledge and attitudes of residents of the buffer zone surrounding SNP to identify directions for future research and conservation efforts aimed at promoting hog deer populations.

Efficient and reliable methods to survey population density are important for monitoring hog deer over time. Previously, hog deer in SNP have been monitored using distance sampling along line transects but data from remote-sensing cameras could be an alternative approach for population surveys. In Chapter 2, I compared the estimates produced by and costs required to estimate hog deer density using two methods, distance sampling along line transects and camera trapping combined with random encounter models (REM). The estimate produced by distance sampling (33.58 ± 8.48 individuals per km^2) was more than double the estimate produced by camera trapping (12.95 ± 0.04 individuals per km^2). Of the two methods, camera trapping with REM produced a density estimate more in line with density estimates reported in the literature. However, camera trapping with REM cost $6,130 more and required 240 hours more time for data processing compared with distance sampling, which make REM impractical for projects with limited funding. In addition, estimates produced using REMs can be sensitive to parameter estimation, particularly the day range and effective detection distance (Rowcliffee et al., 2008). These findings highlight the challenges of estimating density and underscore the need for further studies replicated over space and time to refine methods for density estimation.

In addition to efficient methods to monitor wildlife populations, understanding the attitudes and knowledge of local people towards hog deer is important in developing successful conservation efforts. In chapter 3, I worked with research assistants to interview 30 residents of the buffer zone surrounding SNP to investigate three questions: 1) how much knowledge and experience do local people have with hog deer; 2) what are the attitudes of local people towards hog deer conservation; and 3) what are the current and preferred management approaches for mitigating human-deer conflict in the buffer zone? Interview participants had considerable knowledge of deer as a species group, but approximately half of participants did not distinguish hog deer from other species of deer. Moreover, I found that participants had positive attitudes towards deer conservation, probably because deer rarely cause direct harm to people and livestock and are important for supporting the local wildlife-based tourism industry. Participants explained that current management practices are largely effective at mitigating crop damage by deer. For example, most farmers chase deer away from their agricultural lands by making noise, lighting a fire or with the help of dogs. Interview participants emphasized the importance of deer in the local tourism economy, which provides revenue through the hospitality sector. In terms of recommendations to further reduce deer-human conflict, interview participants suggested that regular fencing or electric fencing would reduce animal movements onto agricultural land.

Participants were not in favour of programs that provide monetary compensation for damage caused by wildlife.

My research provided insights into population monitoring techniques and community support for hog deer conservation. To date, no studies in Nepal have compared these density estimation methods. For more robust comparison, my study highlights the importance of replicating density estimates using both methods over time and space. In addition, these methods should be compared with established density estimation techniques, such as mark-recapture or stratified random block counts. Moreover, my results revealed that residents of the buffer zone around SNP have considerable knowledge of deer species and positive attitudes towards hog deer conservation; these perspectives towards deer specifically have not been studied previously. Therefore, my research serves as a baseline for future studies exploring community perspectives on deer conservation. Local people may assist in density estimation, thereby supporting population monitoring efforts. Finally, these findings highlight opportunities for educational initiatives, such as posters and brochures showcasing different deer species, to raise awareness about deer diversity within SNP and surrounding areas. Such efforts could build on existing enthusiasm for deer conservation by promoting awareness of the conservation needs of individual deer species. In addition, education could empower community members to become more involved in monitoring population trends through community science programs (Bliss et al., 2001; Bajracharya et al., 2006)

4.2 Limitations

Adequate replication of surveys over space and time is important for producing reliable population estimates for wildlife (Buckland et al., 2004). My field surveys were conducted exclusively in grassland habitat, which is the primary habitat of hog deer in the western sector of SNP (Dhungel & O'Gara, 1991). This decision was made to avoid forested areas where controlled burns were being conducted by park staff to promote regeneration of Sal (*Shorea robusta*) seedlings and because hog deer were most likely to be found in grassland habitat. The focus on grassland habitat probably contributed to the unrealistically high density estimate produced by distance sampling. Future studies should cover other habitat types so that density estimates can be averaged across habitat types at the landscape level to estimate total population size across an area of interest, such as SNP.

Density estimates can have a high degree of variability due to seasonal changes in wildlife populations as well as uncertainty related to methods used for estimation (Buckland et al., 2001; Palencia et al., 2021). Collecting data over multiple years and seasons would enable a comparison of the variability of estimates between distance sampling and random encounter models. In addition, I recommend comparing these methods to a density estimation method that uses mark-recapture or block counts as these methods are well established for ungulate species and could be used to assess how well other approaches approximate the true population size of hog deer (i.e., accuracy) (Koetke et al., 2024).

My data from line transects suggested that hog deer moved away from the transect line in response to approaching observers; this behaviour violates an assumption of distance sampling and could have contributed to the unrealistically high density estimate produced using this method. Therefore, I recommend that future studies examine whether the issue can be mitigated during field surveys (e.g., by conducting surveys at a different time of day or year or on foot instead of using elephants).

Further, I conducted distance sampling with a lower survey effort (i.e. smaller sample size) compared with other studies. I surveyed a total length of 34 km whereas previous studies surveyed >100 km of transects (Adhikari and Thapa, 2013; Karki et al., 2015; Wegge et al., 2018). Less sampling effort would lead to more uncertainty in the density estimate (Buckland et al., 2005). Thus, an expanded survey effort with a larger number of transects sampled in different habitat types over multiple years and seasons would establish a more reliable estimate of hog deer density using distance sampling.

Although I collected demographic characteristics such as age classes, ethnicities, religions of the participants, I did not explore demographic differences among attitudes towards and knowledge of deer conservation. Previous studies have found that demographic factors such as age, education level, income, and livestock holdings shape people's views on wildlife (Dhungana et al., 2022; Mir et al., 2016; Shahi et al., 2022).Future research, using a larger sample of the local population, should investigate these associations. Although I recorded the occupation of the participants, these data do not capture the extent to which local people benefit from nature-based tourism. Future research should investigate the relationship between occupations and the economic benefits derived from wildlife tourism in greater detail.

4.3 Management Implications

My findings highlight a need for further comparisons of density estimation methods for hog deer in SNP. The density estimates obtained from distance sampling along line transects and camera data combined with an REM differed substantially. Also, those methods required different amounts of effort in terms of time and cost, making it challenging to recommend the most suitable approach for future monitoring of hog deer in SNP. To better understand the differences between methods, I recommend replicating density estimates across time and space using both approaches to enable a more robust comparison. For example, stratifying the park into different areas based on habitat or other characteristics that might influence hog deer and calculating estimates for different areas with repeated sampling over time would allow for an evaluation of precision of the density estimation methods.

My estimate using camera data combined with an REM produced an estimate aligned with previous estimates of hog deer density; however, there are no data from censuses or methods such as mark-recapture that can be used for comparison with my estimate. Therefore, I recommend that future research on hog deer density include a method that is considered 'gold standard' for population estimation, such as a mark-recapture or stratified random block count design (Corlatti et al., 2015; Peterson et al., 2020). Both approaches are time-consuming and expensive and would require placing collars on some hog deer. A randomized block count would probably involve surveys by helicopter to count all individuals within pre-defined blocks of habitat. Both studies would require considerable time and effort but would produce density estimates that could serve as a baseline for periodic assessments or for comparison with alternative methods, such as distance sampling.

Obtaining population estimates from remote camera data is appealing because camera images can be used to collect data on occurrence, daily activity patterns, and behaviour of a variety of species simultaneously. Moreover, cameras can be incorporated into long-term monitoring programs relatively easily and can be used to monitor rare species or new species occurrences (Sadadev et al., 2024). Although my findings suggest that the density estimate provided by REM was realistic compared with other estimates in the literature, further studies are required to assess the sensitivity of the estimate to variation in parameters used in the model. For example, previous studies have highlighted the sensitivity of estimates from REMs to parameter estimates for day range and effective detection distance. If future research can validate and refine parameter estimation approaches, REM could offer a promising alternative to distance sampling for estimating hog deer densities and could be particularly beneficial for long-term, multi-species and multi-season studies (Pfeffer et al., 2018). For example, in Nepal, REM models could be used to estimate the densities of tiger prey as DNPWC conducts the periodic tiger assessment every four years using camera traps. These same camera traps could be used to assess the density of tiger prey, optimizing both cost and time.

The interviews I conducted with residents of the buffer zones surrounding SNP revealed that participants had considerable local knowledge of deer as a species group but not necessarily about hog deer as a distinct species. Moreover, participants expressed positive attitudes towards deer conservation. Combined, these findings suggest that future conservation efforts should include focus groups involving park managers and local people to discuss conservation needs for deer. Part of these discussions should focus on exploring local knowledge of deer to better understand conservation needs and associated activities. In addition, discussions should examine whether there is a need for further education about groups of deer, such as hog deer, that might have distinct habitat requirements that necessitate species-specific conservation plans. Although species taxonomy defined by local knowledge may not agree with that of Western Science, sharing of information among knowledge systems could lead to improved understanding of ecology and approaches for monitoring changes in populations over time (Meadows, 2011).

If possible, education could be incorporated as a part of promoting tourism by training residents of the buffer zone and building their capacity as nature guides or natural history interpreters. Ideally, training could be designed collaboratively by Park staff and buffer zone residents through round-table discussions or workshops. Such programs would allow people to learn about deer and also share their knowledge and experiences (Rutherford et al., 2009). Also, training would increase opportunities for income related to tourism and strengthen the connections between buffer zone residents and local wildlife and ecosystems. Empowering residents to work in the tourism sector can add value to the community by fostering sustainable livelihoods directly tied to conservation efforts. Cultural exchanges between visitors and local communities often encourage the preservation and celebration of traditional practices, including culture attire, tools, songs, and dance (KC et al., 2015; Thapa, 2012). Interactions between visitors and community members also contribute to a broader understanding and appreciation of cultural heritage, enhance the overall tourism experience while solidifying community identity and pride. The expansion of ecotourism in SNP could yield similar benefits for surrounding communities. By attracting nature enthusiasts, conservationists, and cultural tourists, ecotourism could create a more sustainable economy built on preserving the park's rich biodiversity and cultural heritage. Revenue generated from ecotourism could be reinvested in community development initiatives and conservation education programs. Moreover, involving local people in ecotourism fosters a sense of ownership and responsibility for wildlife conservation. With proper planning, SNP could serve as a model for balancing ecotourism and biodiversity conservation with cultural preservation and community well-being.

The compensation process for wildlife-induced damage in Nepal is often viewed as ineffective due to its time-consuming and complex nature, coupled with inadequate compensation amounts that fail to offset the actual losses experienced by affected individuals (Sahi et al., 2022, 2023). I found that many interview participants shared these concerns about compensation and favored the installation of physical barriers, such as fencing. Though SNP has installed some barbed wire fencing around the Park, species such as monkeys, wild boars, wild elephants and nilgai continue to enter agricultural areas and cause damage to crops. This on-going conflict with wildlife underscores the need for park managers to reassess and adapt conflict mitigation strategies. Electric fencing can be more effective than barbed wire fencing for reducing the movement of wild elephants, wild boars, tigers and one-horned rhinoceros into agricultural areas and minimizing the damage they cause to crops and livestock (Neupane et al., 2018; Sapkota et al. 2014). Therefore, park managers could consider prioritizing the installation of electric fencing in areas most affected by wildlife conflicts while continuing to cover less impacted areas with barbed wire fencing. This phased and targeted approach would optimize resources while addressing the immediate concerns of the most affected communities.

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Appendix I: Supplemental Information for Chapter 2

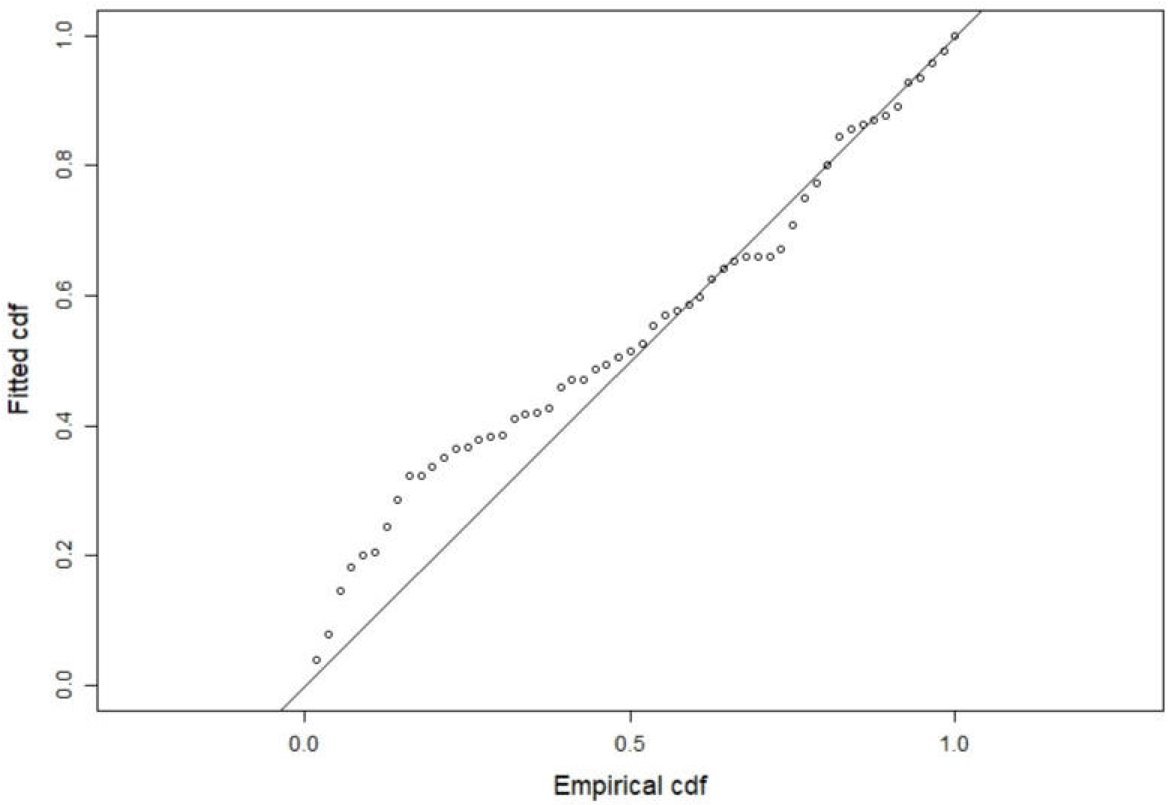

Figure 11: Q-Q plot of hazard rate cosine function fitted to hog deer transect data. At smaller distances from the transect line, the values are deviated from the empirical and fitted cumulative distribution functions but at the increased distances, that values are closer to the transect line.

Appendix II: Supplemental Information for Chapter 3

Information Letter and Consent Form: Attitudes towards Hog deer *(Axis porcinus)* in Shuklaphanta National Park, Nepal

Dear Prospective Participant,

We would like to invite you to participate in a research project entitled "Attitudes towards Hog deer in Shuklaphanta National Park". The goal of this research is to understand how people who live near the Park feel about Hog deer, including their experiences interacting with Hog deer and thoughts on appropriate conservation and management activities. The research is being done by Bipana Maiya Sadadev, who is a resident of Kathmandu, Nepal, and who is a Master of Science Student studying at the University of Northern British Columbia, Canada. Bipana is not able to be here in person, so I am a research assistant conducting the interview on her behalf.

This research is being funded by the Rufford Foundation.

The Rufford Foundation is a registered charity in the United Kingdom that funds nature conservation projects across the developing world. One of their goals is to support early-career researchers to achieve their conservation goals and become leaders in conservation. In the last 20 years, the Foundation has funded >5100 grants in over 150 countries.

If you choose to participate in this research, we will ask you questions about your personal background, your knowledge of Hog deer and other deer species, and your opinions about Hog deer conservation. The interview is expected to last about 30-60 minutes. In thanks for your time, we would like to offer you Rs. 100 as compensation, which we will provide at the end of the interview.

Before beginning the interview, we would like to ensure that you are fully informed about the collection and use of information that you share with us and that you consent to participation in the study.

Participation in any research project can have risks that must be weighed against the benefits of the research. In this case, the questions we ask may cause negative reactions or emotions that could be harmful to participants. Should you feel any negative emotions following this interview, we encourage you to contact the local health authority to discuss your concerns (contact information below). In addition, there is a possibility that this study will lead to the implementation of conservation actions that could be considered controversial or restrictive to some members of the community (e.g., reduced access to protected areas). Despite these risks, we anticipate that data from the survey may lead to conservation actions that are informed by the values of local people and which could benefit local communities (e.g., compensation programs for lost crops, increased opportunities to participate in eco-tourism). In addition, there may be potential conservation benefits to hog deer and other species resulting from this project which would have positive effects on local ecosystems.

As researchers, we have an ethical duty to safeguard the information you provide to us and to maintain your privacy. Although our intent is not to elicit responses about activities that are considered illegal, there is a risk that a description of illegal activities, such as poaching, may be revealed during the interviews. Should this occur, we will not disclose the information to the concerned authorities. As described below, all information that could link you or others to the responses will be removed as soon as possible after the interview. After interviews are complete, any information collected during the interviews that could be used to identify individual participants or other community members will be removed, including any references to illegal activity. The de-identified, cleaned data along with a summary report will be shared with staff from Shuklaphanta National Park and the Department of National Parks and Wildlife Conservation, Nepal, in electronic and paper formats. All demographic information collected during the interviews will be summarized and presented as aggregate values only. The information will also be shared in Bipana's thesis and scientific publications and presentations. The information will also be presented as part of community meetings in 2024 or 2025.

Upon consenting to participation in this study, you will be assigned a unique participant code so your name will not be associated with your interview responses. Only the lead researchers (Bipana Maiya Sadadev), her supervisor (Heather Bryan), and myself will have access to the raw data after they are collected. These data will be stored on a secure server. Information collected during interviews (including audio recordings and written notes) will contain only your unique participant code. These data will be stored on an encrypted, password-protected computer and a secure server. Upon completion of interviews, the responses from interviews will be transcribed into a spreadsheet and all information that could be used to identify participants or other community members will be removed. Once the data have been transcribed from the original audio files and notes, they will be stored on a secure server and may be used for future research by the original researchers. Raw data files (audio recordings and notes) will be destroyed two years after the results of the study are published.
After the interview is complete, you will not be able to withdraw from the research as we will not retain any information linking your responses with your name or identity.

If you agree, we would like to record your responses using an audio recording device. The recording will enable us to verify that we have recorded your answers accurately after the interview.
Please note that by consenting to participate in this research, you are not waiving any rights to legal recourse in the event of research-related harm.

Contact Information:

Please address any questions about the scientific aspects of this research to Bipana Maiya Sadadev, MSc Candidate at the University of Northern British Columbia, (sadadev@unbc.ca) or Heather Bryan, Assistant Professor at the University of Northern British Columbia (heather.bryan@unbc.ca), or the Warden or range staff of Shuklaphanta National Park.

Please address any questions about possible ethical issues in this research to: Isobel Hartley, Research Ethics Officer, University of Northern British Columbia (isobel.hartley@unbc.ca)

Should you experience any negative emotions following participation in this survey, we encourage you to contact: Nepal Ambulance Service and call 102

सूचना पत्र र सहमति फारम: शुक्लाफाँटा राष्ट्रिय निकुञ्जमा हग डियर (एक्सिस पोर्सिनस) प्रति मनोवृत्ति, नेपाल

प्रिय सम्भावित सहभागी,

हामी तपाईंलाई "शुक्लाफाँटा राष्ट्रिय निकुञ्जमा हग डियरको दृष्टिकोण" शीर्षकको अनुसन्धान परियोजनामा भाग लिन आमन्त्रित गर्न चाहन्छौं। यस अनुसन्धानको लक्ष्य पार्क नजिकै बस्ने मानिसहरूले हग डियरको बारेमा कस्तो महसुस गर्छन् ;fy ;fy} हग डियरसँग अन्तरक्रिया गरेको अनुभव र उपयुक्त संरक्षण र व्यवस्थापन गतिविधिहरूमा विचारहरू बुझ्नु हो । नेपाल, काठमाडौं निवासी र क्यानडाको नर्दन ब्रिटिस कोलम्बिया विश्वविद्यालयमा स्नातकोत्तर गर्दै आएकी विपना मैया सदादेवले उक्त अनुसन्धान गरिरहेकी छन् । बिपना यहाँ व्यक्तिगत रूपमा आउन सक्षम छैन, त्यसैले म उनको तर्फबाट अन्तर्वार्ता लिने अनुसन्धान सहायक हुँ।

यो अनुसन्धानnfO{ रफर्ड फाउन्डेसनn] ;xof]u u/]sf] छ।

रुफर्ड फाउन्डेसन युनाइटेड किंगडममा दर्ता गरिएको परोपकारी संस्था हो जसले विकासोन्मुख विश्वभरि प्रकृति संरक्षण परियोजनाहरूलाई पैसा दिन्छ। तिनीहरूको लक्ष्यहरू मध्ये एक प्रारम्भिक क्यारियर अनुसन्धानकर्ताहरूलाई उनीहरूको संरक्षण लक्ष्यहरू प्राप्त गर्न र संरक्षणमा नेता बन्न समर्थन गर्नु हो। विगत २० वर्षमा, फाउन्डेसनले 150 भन्दा बढी देशहरूमा 5100 भन्दा बढी अनुदानहरू उपलब्ध गराएको छ।

यदि तपाइँ यस अनुसन्धानमा भाग लिन छनौट गर्नुहुन्छ भने, हामी तपाइँलाई तपाइँको व्यक्तिगत पृष्ठभूमि, हग डियर र अन्य हिरण प्रजातिहरुको बारेमा तपाइँको ज्ञान, र हग डियर संरक्षण को बारे मा तपाइँको राय को बारे मा केहि प्रश्नहरु सोध्नेछौं। अन्तर्वार्ता #)–^) मिनेट सम्म चल्ने अपेक्षा गरिएको छ। तपाईंको समयको लागि धन्यवाद, हामी तपाईंलाई रु. 100 क्षतिपूर्तिको रूपमा, जुन हामी अन्तर्वार्ताको अन्त्यमा प्रदान गर्नेछौं।

अन्तर्वार्ता सुरु गर्नु अघि, हामी यो सुनिश्चित गर्न चाहन्छौं कि तपाईंले हामीसँग साझेदारी गर्नुभएको जानकारीको सङ्कलन र प्रयोगको बारेमा तपाईंलाई पूर्ण जानकारी छ र तपाईंले अध्ययनमा सहभागी हुन सहमत हुनुहुन्छ।

कुनै पनि अनुसन्धान परियोजनामा सहभागिता जोखिम हुन सक्छ जुन अनुसन्धानका फाइदाहरू विरुद्ध तौलिएको हुनुपर्छ। यस अवस्थामा, हामीले सोध्ने प्रश्नहरूले नकारात्मक प्रतिक्रिया वा भावनाहरू निम्त्याउन सक्छ जुन सहभागीहरूलाई हानिकारक हुन सक्छ। यदि तपाइँ यो अन्तर्वार्ता पछि कुनै नकारात्मक भावनाहरू महसुस गर्नुहुन्छ भने, हामी तपाइँलाई तपाइँको चिन्ता बारे छलफल गर्न स्थानीय स्वास्थ्य प्राधिकरणलाई सम्पर्क गर्न प्रोत्साहन दिन्छौं। थप रूपमा, यस अध्ययनले समुदायका केही सदस्यहरूलाई विवादास्पद वा प्रतिबन्धित मानिने संरक्षण कार्यहरूको कार्यान्वयनमा लैजाने सम्भावना छ (जस्तै, संरक्षित क्षेत्रहरूमा पहुँच कम)। यी जोखिमहरूको बावजुद, हामी अनुमान गर्छौं कि सर्वेक्षणको तथ्याङ्कले संरक्षण कार्यहरू निम्त्याउन सक्छ जुन स्थानीय मानिसहरूको मूल्यहरूद्वारा सूचित गरिएको छ र जसले स्थानीय समुदायहरूलाई फाइदा पुऱ्याउन सक्छ (जस्तै, हराएको बालीहरूको लागि क्षतिपूर्ति कार्यक्रमहरू, पारिस्थितिक पर्यटनमा भाग लिने अवसरहरू बढाउने)। थप रूपमा, यस परियोजनाको परिणामस्वरूप हग डियर र अन्य प्रजातिहरूको लागि सम्भावित संरक्षण लाभहरू हुन सक्छन् जसले स्थानीय पारिस्थितिकी प्रणालीहरूमा सकारात्मक प्रभाव पार्न सक्छ।

अन्वेषकहरूको रूपमा, तपाईंले हामीलाई उपलब्ध गराउनुभएको जानकारीको सुरक्षा गर्नु र तपाईंको गोपनीयता कायम राख्नु हाम्रो नैतिक कर्तव्य हो। यद्यपि हाम्रो उद्देश्य गैरकानूनी मानिने गतिविधिहरूको बारेमा प्रतिक्रियाहरू प्राप्त गर्ने होइन, तर अन्तर्वार्ताको क्रममा अवैध शिकार जस्ता गैरकानूनी गतिविधिहरूको विवरण प्रकट हुन सक्ने जोखिम छ। यदि यस्तो भयो भने, हामी सम्बन्धित अधिकारीहरूलाई जानकारी खुलासा गर्दैनौं। तल वर्णन गरिए अनुसार, तपाइँ वा अरूलाई प्रतिक्रियाहरूमा लिङ्क गर्न सक्ने सबै जानकारीहरू अन्तर्वार्ता पछि सकेसम्म चाँडो हटाइनेछ।

अन्तर्वार्ता पूरा भएपछि, अन्तर्वार्ताको क्रममा सङ्कलन गरिएका व्यक्तिगत सहभागी वा अन्य समुदायका सदस्यहरू पहिचान गर्न प्रयोग गर्न सकिने कुनै पनि जानकारी र अवैध गतिविधिको जानकारी सd]त हटाइनेछ। पहिचान नभएको, सफा गरिएको तथ्याङ्क शुक्लाफाँटा राष्ट्रिय निकुञ्ज र राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण विभाग, नेपालका कर्मचारीहरूलाई संक्षिप्त प्रतिवेदनसहितको इलेक्ट्रोनिक र कागजी ढाँचा k]z गरिनेछ। अन्तर्वार्ताका क्रममा सङ्कलन गरिएका सबै जनसांख्यिकीय जानकारीलाई संक्षेपमा प्रस्तुत गरिनेछ र समग्र मानहरूको रूपमा मात्र प्रस्तुत गरिनेछ। यो जानकारी विपनाको थेसिस र वैज्ञानिक प्रकाशन र प्रस्तुतिहरूमा पनि साझा गरिनेछ। @)@$ वा @)@% को सामुदायिक बैठकहरूमा पनि tL जानकारीx? प्रस्तुत गरिनेछ।

यस अध्ययनमा सहभागिताको लागि सहमति दिएपछि, तपाईंलाई एक अद्वितीय सहभागी कोड प्रदान गरिनेछ जुन तपाईंको व्यक्तिगत डेटा (जस्तै, नाम र ठेगाना) तपाईंको अन्तर्वार्ता प्रतिक्रियाहरूसँग लिङ्क गर्न प्रयोग गरिनेछ। केवल प्रमुख अनुसन्धानकर्ताहरू (बिपना मैया सदादेव), उनको सुपरभाइजर (हेदर ब्रायन) र मसँग मात्र कच्चा तथ्याङ्कहरूमा पहुँच हुनेछ। यी

डाटा सुरक्षित सर्भरमा भण्डारण गरिनेछ। अन्तर्वार्ताको समयमा सङ्कलन गरिएको जानकारी (अडियो रेकर्डिङ र लिखित नोटहरू सहित) तपाईंको अद्वितीय सहभागी कोड मात्र समावेश हुनेछ। यी डाटा एन्क्रिप्टेड, पासवर्ड-सुरक्षित कम्प्युटर र सुरक्षित सर्भरमा भण्डारण गरिनेछ। अन्तर्वार्ता समाप्त भएपछि, अन्तर्वार्ताबाट प्राप्त प्रतिक्रियाहरूलाई स्प्रिेडसिटमा ट्रान्सक्राइब गरिनेछ र सहभागीहरू वा अन्य समुदायका सदस्यहरू पहिचान गर्न प्रयोग गर्न सकिने सबै जानकारीहरू हटाइनेछ। मूल अडियो फाइलहरू र नोटहरूबाट डाटा ट्रान्सक्राइब गरिसकेपछि, तिनीहरू सुरक्षित सर्भरमा भण्डारण हुनेछन् र मूल शोधकर्ताहरूद्वारा भविष्यको अनुसन्धानको लागि प्रयोग गर्न सकिन्छ। अध्ययनको नतिजा प्रकाशित भएको दुई वर्षपछि कच्चा डाटा फाइलहरू (अडियो रेकर्डिङ र नोटहरू) नष्ट हुनेछन्।

अन्तर्वार्ता पूरा भएपछि, तपाईंले अनुसन्धानबाट पछि हट्न सक्नुहुने छैन किनभने हामी तपाईंको नाम वा पहिचानसँग तपाईंको प्रतिक्रियाहरू लिङ्क गर्ने कुनै पनि जानकारी राख्ने छैनौं।

यदि तपाईं सहमत हुनुहुन्छ भने, हामी अडियो रेकर्डिङ उपकरण प्रयोग गरेर तपाईंको प्रतिक्रियाहरू रेकर्ड गर्न चाहन्छौं। रेकर्डिङले हामीलाई अन्तर्वार्ता पछि तपाईंको जवाफहरू सही रूपमा रेकर्ड गरेको छ भनी प्रमाणित गर्न सक्षम बनाउँछ।

कृपया ध्यान दिनुहोस् कि यस अनुसन्धानमा भाग लिनको लागि सहमति दिएर, तपाईंले अनुसन्धान-सम्बन्धित हानिको घटनामा कानूनी सहाराको कुनै पनि अधिकार त्याग्नु भएको छैन।

सम्पर्क जानकारी:

उत्तरी ब्रिटिश कोलम्बिया विश्वविद्यालय मा एमएससी उम्मेदवार बिपना मैया सदादेव(sadadev@unbc.ca) वा उत्तरी ब्रिटिश कोलम्बिया विश्वविद्यालयका सहायक प्राध्यापक हेदर ब्रायन (heather.bryan@unbc.ca) वा शुक्लाफाँटा राष्ट्रिय निकुञ्जका वार्डन वा दायरा कर्मचारीहरूलाई यस अनुसन्धानको वैज्ञानिक पक्षहरूको बारेमा कुनै प्रश्नहरू पठाउनुहोस्।

कृपया यस अनुसन्धानमा सम्भावित नैतिक मुद्दाहरूको बारेमा कुनै पनि प्रश्नहरूलाई सम्बोधन गर्नुहोस्: Isobel Hartley, अनुसन्धान नैतिक अधिकारी, उत्तरी ब्रिटिश कोलम्बिया विश्वविद्यालय (isobel.hartley@unbc.ca)

यदि तपाईंले यस सर्वेक्षणमा भाग लिएपछि कुनै नकारात्मक भावनाहरू अनुभव गर्नुभयो भने, हामी तपाईंलाई सम्पर्क गर्न प्रोत्साहित गर्छौं: नेपाल एम्बुलेन्स सेवा !)@ मा कल गर्नुहोस्।

Attitudes towards Hog deer *(Axis porcinus)* in Shuklaphanta National Park, Nepal

Survey Number: **Surveyor:** **Duration:**
Date: **Locality:**
Information Letter Read: a) Yes b) No
Consent given: a) Yes b) No
Part I: Socio-Demographic Characteristics

1. **Gender**:
2. **Age:** **Distance of household from Park Boundary :**
3. **What is your family size?** …………. Adult ……….. Child ……………
4. **What is your occupation? For how many years have you been employed in your occupation?**

Occupation	Year	Annual Household Income

5. **What is your religion? Ethnicity? Caste?**

Social/Cultural Group	Specify Name
Religion	
Ethnicity	
Caste	
Other	

Brahmin-B, Chhetri-C, Gurung- G, Magar-M, Tharu-TR, Tamang-T

6. **Education**

Education	Program type
Can you read and write? (Y/N)	
Educational qualifications (Elementary, high school, university degree, diploma, technical program)	
Access to environmental education and Participation in environmental conservation program	

7. **Livestock Holdings**

Livestock Holdings			
How many animals do you have?	**1-**Cow **2-**Calf **3-**Buffalo	**4-**Goat **5-**Bull **6-**Pig	**7-**Sheep **8-**Poultry **9-**Honey Bees
What animal products do you sell?	**1-**Milk **2-**Eggs **3-**Ghee	**4-**Cheese **5-**Meat **6-**Honey	**7-**Curd **8-**Bees Wax

8. **Agricultural crops: Which crops do you grow?**

1. Maize 2. Wheat 3. Paddy	4. Potato 5. Peas 6. Sugarcane	7. Barley 8. Mustard 9. Millet	10. Jute 11. Cotton 12. Vegetables

Part II: Knowledge and experience with Hog deer and other deer species

9) Out of the species shown in the following images, which ones can you identify? Which ones have you seen? (Show the photographs of different ungulate species)

	Identified	**Seen (Y/N), If Yes (When, Where) Show on map**
Hog deer		
Spotted Deer		
Swamp Deer		
Barking Deer		
Wild Boar		
Sambar		

10) What do you call Hog deer (or deer) in your local language? ……………………………….

11) Do you usually see hog deer (or deer) alone or in groups?

a) Alone b) Groups If group, how many individuals/group? ……………….

12) **In what ways do hog deer (or deer) influence your farm, agricultural land, or livestock? What are the consequences?**

13) **How do you respond when you see hog deer (or deer) on farm land?**

Part III: Conservation and management of Hog deer (or deer)

14) **To what degree do you like seeing Hog deer in your locality?**
    a) strongly dislike b) dislike c) neutral d) like e) strongly like

15) **To what degree do you feel that conservation of Hog deer (or deer) is important?**
    a) strongly disagree b) disagree c) neutral d) agree e) strongly agree

16) **What does conservation of hog deer (or deer) mean to you?**

17) **Can you describe any changes in hog deer (or deer) abundance over time? What might be the reason behind any changes in Hog deer (or deer) sightings overtime?**

18) **Do you get any compensation from the park or buffer zone management committee when Hog deer (or deer) damage crops or livestock?**
    a) Yes b) No c) Don't know

    If yes, what amount? How easy is it to access the compensation program?
    ……………………………………………………………………………………….
    If no, do you think a compensation program or subsidizing fencing would help address potential conflicts between people and hog deer (or deer)?

19) Can you describe the role of hog deer (or deer) in the local tourism economy?

20) What actions could be used to conserve hog deer (or deer)?

21) Is there anything else you would like to tell me about hog deer (deer) or conservation measures for hog deer (or deer)?