A COMPARATIVE STUDY OF ABUNDANCE OF TIGER PREY BASE IN BARDIA-KATARNIAGHAT (KHATA) CORRIDOR AND SOUTH-WEST CORNER OF BARDIA NATIONAL PARK, NEPAL

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FOREWORD

This master thesis has been written as an academic requirement for the completion of Master of Science in Tropical Ecology and Management of Natural Resources in the Norwegian University of Life Sciences.

I would like to express special gratitude to my supervisors – Assistant Professor Mr. Torbørn Haugaasen and Professor Mr. Per Wegge for providing excellent guidance in the completion of my thesis. I would like to thank the Head of National Trust for Nature Conservation, Mr. Shanta Raj Jnawali for granting me the accommodation and necessary assistance for my research in Bardia Conservation Project Office, Thakurdwara, Bardia. I would also like to thank Ranger Mr. Bintiram Chaudary and Wildlife technician Mr. Firu Tharu for assisting me in the field survey.

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Ajaya Nagarkoti, Ås, 15/7/2012

ABSTRACT

The current study was carried out in Bardia National Park and in the Bardia-Katarniaghat (Khata) corridor, which is one of five priority areas identified by Terai Arc Landscape Program (TAL) for habitat restoration due to heavy degradation of forest. The study was conducted from 15th October to 26th November 2011. The main objectives of the study were to compare the composition and abundance of tiger prey in both study areas and to draw inference on tiger habitat quality in the corridor. The line-plot pellet count technique of Wegge (1976) was adopted to assess the composition and abundance of tiger prey. Habitat compositions in the park and the corridor were determined on the basis of proportional length of different habitats along transects. Land use changes in the corridor from 1997 to 2011 were found out by the help of GIS using a topographic map and a Google Earth image.

Corridors are connections between separate areas of similar habitat (Bolen & Willam 1995) and geographical extensions, continental or maritime, whose function is to connect areas and facilitate the movement of plants and animals and provide natural conditions that guarantee their conservation (Rivera et al. 2002). The study found out that the abundance of major tiger prey species like chital (*Axis axis*) and hog deer (*A. porcinus*) was extremely low in the Khata corridor compared to the south-western part of the park. The less abundant swamp deer (*Cervus duvauceli*) was restricted to phanta in the park, but was absent in the corridor. Other preferred prey species, such as sambar deer (*C. unicolor*) was rare in the park, but absent in the corridor. Similarly, nilgai (*Boselaphus tragocamelus*) and barking deer (*Muntiacus muntjac*) were scarce in both study areas. Livestock pellet groups were recorded only in the corridor with the highest abundance after wild boar. Relatively small areas of important prey habitats like phanta and tallgrass floodplain (($p \leq 0.05$) in the corridor than in the park, and their poor quality was the main reason for the low density of chief tiger prey species in the corridor.

Habitat assessment in the Khata corridor showed that the forest area remained unchanged and there was an insignificant increase in other land types from 1997 to 2011. The study indicated that the effect of past anthropogenic activities, current excessive livestock pressure and infestation of the alien plant *Lantana camara* were important factors affecting the habitat quality in the corridor. This suggested that tiger habitat quality was not satisfactory in the corridor. Nevertheless, the higher density of wild boar in the corridor may fulfill the feeding requirements of the tiger and can help its transboundary dispersal in some extent. On the other hand, the tiger population may increase with the restoration of habitats, which in turn may increase tiger human conflicts due to the small habitat area. All these issues should be

addressed to restore the tiger habitat in the Khata corridor and facilitate its smooth dispersal through it.

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INTRODUCTION

The alteration of habitat for land-use development is a major reason for the loss of biodiversity (Crist et al. 2000; Sala et al. 2000). Habitat alteration aids to habitat fragmentation either by decreasing the total area of habitat or by splitting the remaining area into more isolated pieces (Wilcove et al. 1986). Habitat fragmentation affects numerous ecological processes across multiple spatial and temporal scales, including changes in abiotic regimes, shifts in habitat use, altered population dynamics, and changes in species compositions (Schweiger et al. 2000). Fragmentation of habitat is second largest threat to wildlife due to the formation of habitat-island, limited dispersal for new individual resulting to high competition and risk of inbreeding (DNPWC/MFSC/GoN, 2007). The idea of providing a corridor of habitat to connect natural environments and populations that would otherwise be isolated as result of human activity is one of the earliest practical recommendations arising from the worldwide concern over the ever-worsening loss and fragmentation of natural habitats (Bennett 1997). In ecological context, corridors are connections between separate areas of similar habitat (Bolen & Willam 1995) and geographical extensions, continental or maritime, whose function is to connect areas and facilitate the movement of plants and animals and provide natural conditions that guarantee their conservation (Rivera et al. 2002). Corridor can be a linear corridor (such as a hedgerow, forest strip or river) or stepping stones (an array of small patches of habitat used during movement for shelter, feeding and resting) and various forms of interlinked landscape matrices that allow individuals to survive during movement between habitat patches (Bennett & Mulongoy 2006). Corridors help to reduce or moderate some of the adverse effects of habitat fragmentation allowing dispersal of individuals between isolated habitat patches, helping for the long-term genetic interchange and re-colonization of the patches from which populations have been locally extirpated (Bond 2003).

However, the conservation value of corridor has been the subject of fierce debate (Dawson 1994; Rosenberg et al. 1997; Beier & Noss 1998). Bienen (2002) warned that conservation corridors could the spread infectious disease among wildlife. In addition, the preservation of corridors will not militate against additional loss of core habitat (Beier 1993; Rosenberg 1997). Yet, increasing data of carefully designed experiments and project experience has clarified potential value of corridors (Tewksbury et al. 2002; Bennett 2004).

Southern lowland area of Nepal, Terai, is one of the most bio-diverse areas in Asia (Paudel 2012), which harbours some of the remaining natural habitats of tigers (*Panthera tigris*), Asian elephants (*Elephas maximus*) and greater one-horned rhinoceros (*Rhinoceros unicornis*) (Smith & Mishra 1992; Smith et al. 1998). This vast landscape was indirectly preserved until half century ago because high risk of malaria and the government policy of maintaining a natural barrier of thick forest all along the southern border with India for defense against invasion from the British Empire (Shrestha 2004). This restricted large-scale agricultural development and human settlements in the Terai (Gurung 1983; Mishra & Jefferies 1991). By 1954, initiation of malaria eradication changed the ecology of the Terai as the subsequent influx of human population from the hills led to extensive conversion of forest into agricultural land (GoN 2007). Currently, about 43% of the region is covered by forest ranging from intact to heavily degraded (MOPE 2001). Only 19.7% of Tarai forest constitutes five protected areas located in the area (Paudel 2012). This affected the population of large mammals severely by restricting and fragmenting their habitat.

Tiger, which is listed in Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and classed as Endangered category of Red Book of IUCN, once range widely across vast terai landscape. However, an increase in human settlements due to the eradication of malaria (GoN 2007) has fragmented the habitats (Gurung 1983) and resulted in isolated populations. Habitat loss and fragmentation (Wikramanayake et al. 1998; Dinerstein et al. 2007), reduction of prey base (Karanth & Stith 1999; Ranganathan et al. 2008), poaching (Nowell & Jackson 1996; Chapron et al. 2008), and clash with humans (Nyhus & Tilson 2004; Gurung et al. 2008) are regarded as major reasons for the global decline of tiger populations. Surveys conducted between 1987 and 1997 revealed that only three isolated tiger populations persist in Chitwan National Park, Bardia National Park and Shuklaphanta Wildlife Reserve (Smith et al. 1998). Censuses carried out in 1999/2000 and 2005 found 340-350 and 360-370 adult tigers, respectively (DNPWC/MFSC/GoN 2007). However, a recent census completed in 2009 discovered an increased population in Chitwan National Park, but drastic declines in Bardia and Shuklaphanta National Parks (Karki et al. 2009). Reduction in prey populations was concluded as the cause for observed decline in tiger numbers (Karki et al. 2009).

For the conservation of tiger - together with other threatened species in the wild - the government of Nepal started through enactment of National Park and Wildlife Conservation

Act 2029 in 1973, which initiated the delineation of protected areas (PAs) with Chitwan National Park as the first step. These PAs were established with "Strict Protection" principle. Later, buffer zones were declared around National Parks and Wildlife Reserves to decrease human wildlife conflicts in the PAs (DNPWC / MFSC 1999; Dinerstein et al. 1998).

Smith et al. (1998) proposed a metapopulation approach to tiger management based on the isolated populations. The main intension was to re-establish dispersal habitats, which favours genetic exchange and thus helps in demographic rescue. It consequently paved the path for the creation of the Terai Arc Landscape (TAL) project (MFSC 2004), in which the government of Nepal initiated an ambitious landscape scale project to increase the land base for tigers (Smith et al 1999) and restore connectivity between PAs (Wikramanayake et al. 2004). The project was in operation since 2001 as a merger of two existing projects — the Bardia Integrated Conservation Project and the Western Terai Tiger, Rhino and Elephant Conservation Complex, and the initiative became a joint program of Nepal’s Department of National Parks and Wildlife Conservation, the Department of Forests, WWF’s Nepal Program, local communities and NGOs (Bennett & Mulongoy 2006). The main aim of TAL program is to restore Terai Arc Landscape and its forest corridors to facilitate the dispersal and genetic exchange of wildlife populations and ensure the long-term survival of endangered species (MFSC 2004).

The TAL is a vast conservation landscape of approximately 49,500 sq km, stretching from Nepal's Bagmati River in the east to India's Yamuna River in the west (Figure 1). It links 11 transboundary protected areas from Parsa Wildlife Reserve in Nepal to Rajaji National Park in India. It supports many flagship species like the Bengal tiger, greater one-horned-rhinoceros, Asian elephant and other important species. TAL-Nepal spreads over Mahakali River in the West, Bagmati River in the East, Churia ridge in the North and India in the south. The priority areas focused by TAL program for restoration include three sites Mahadevpuri, Lamahi and Dovan referred as bottlenecks where serious barriers to ecological continuity exist, and two corridors - Basanta and Bardia-Katarniaghat (Bennett & Mulongoy 2006). Khata (Bardia-Katarniaghta) corridor is a transboundry corridor which connects the Bardia National Park of Nepal with Katerniaghat Wildlife Sanctuary of India. It is a part of naya muluk (meaning 'new state') returned to Nepal after signing of the treaty of 1947(known as Sugauli Sandhi) which was seized by British India (Yadav 2011). It covers lowland savannah and grassland habitats between the Bardia National Park in Nepal and Katarniaghat Wildlife Sanctuary in India. This linkage was identified as a critical area for restoration in 2000, and restoration work as part of the TAL program commenced in 2001 (Bennett & Mulongoy 2006). The corridor is used by animals like tiger (Gurung 2003; WWF 2005-06; Yadav 2011), rhinos (Gurung 2003) and elephant as dispersal route between these protected areas.

Among the different factors threatening tiger populations, reduction of the prey base is one of the most important (Karanth & Stith 1999). Prey densities should therefore be monitored closely (Karanth & Stith 1999). Tigers are solitary and ambush hunters (Wilson & Mittermeier 2009) requiring >5 kg of meat per day (Sunquist 1981). The tiger diet consists largely of deer species (about 75% in most parts of its range), although it kills prey ranging from amphibians to big animals like gaur (*Bos gaurus*) (Sunquist 1981; Sunquist et al. 1999; Støen & Wegge 1996; Biswas & Sankar 2002).

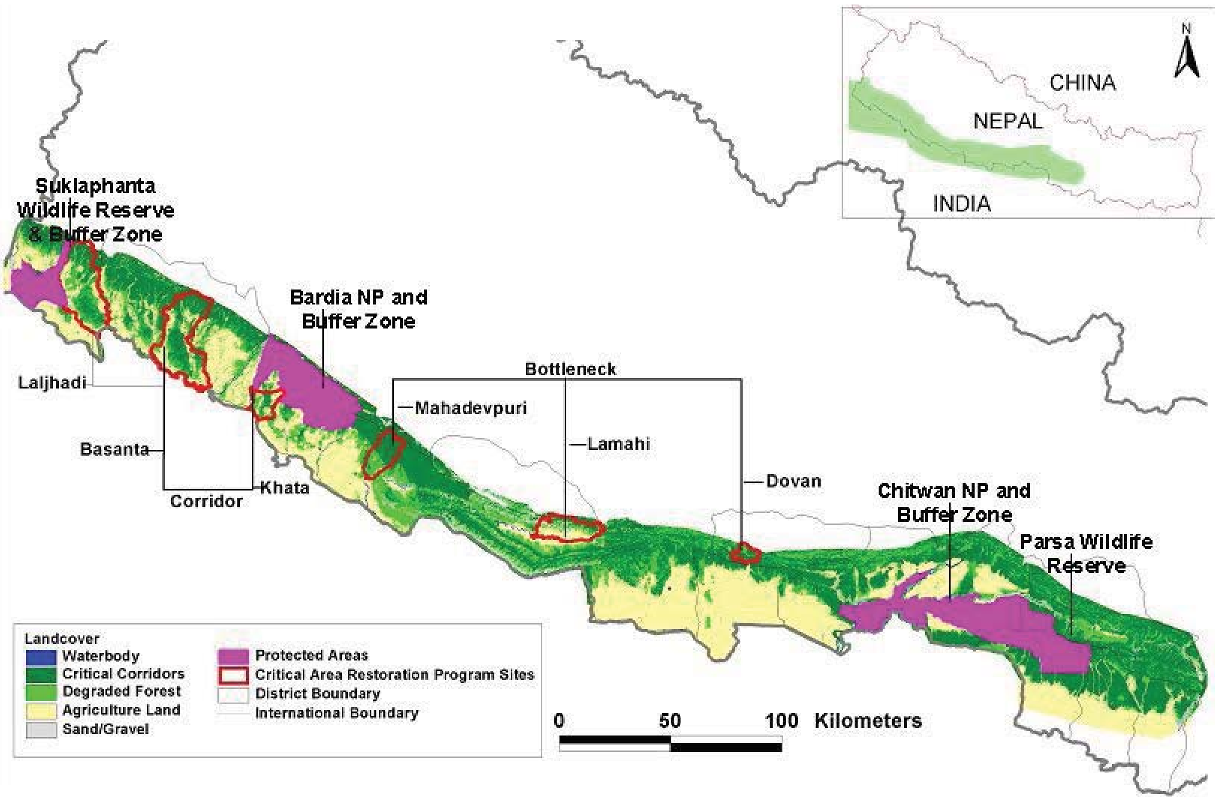

Figure 1. Map of the Terai Arc Landscape (Source: WWF-Nepal)

Tiger prey include chital (Axis axis), nilgai (*Boselaphus tragocamelus*), wild boar *(Sus scrofa*), hog deer (*Axis porcinus*), barking deer (*Muntiacus muntjac*), swamp deer (*Cervus duvauceli*) (Støen & Wegge 1996; Wegge et al. 2009), sambar (*Cervus unicolor*), gaur, four-horned antelope (*Tetracerus quadricornis*) (Karanth & Sunquist 1995; Karanth et al. 2004), chinkara

(*Gazella bennetti*), wild buffalo (*Bubalus bubalis*) and common langur (*Presbytis entellus*) (Bagchi et al. 2003; Karanth et al. 2004). Apart from wild animals, tigers also readily prey on livestock when they are available (Sunquist 1981). In Karnali floodplain of Bardia National Park, bulk of tiger's diet comprised chital, wild boar and hog deer showing preference towards medium-sized prey species (Støen & Wegge 1996; Grey 2009).

OBJECTIVES OF THE STUDY

The broad objective of the current study was to collect ecological information on tiger habitat and prey abundance in the lowland region of Nepal. More specifically I aimed to:

- compare the composition and abundance of tiger prey in the south-west corner of Bardia National Park and in the Khata corridor that connects Bardia National Park with Katarniaghat Wildlife Reserve in India.
- draw inference on tiger habitat quality in the Khata corridor.

RATIONALE

Availability of sufficient prey is vital for the use of corridors by tigers. If prey is scarce in the corridor, human-tiger conflict can arise in terms of increased livestock depredation and human causalities in and around the corridor. So it is important to assess the condition of prey in the corridor. Only a comparative study of prey abundance between the core area (i.e. the park) and the corridor will provide insight into the prey abundance required in the corridor for its use by tiger. In the corridor, different studies (Shrestha 2004; Adhikari & Khadka 2009; Karki 2009) has been carried out to assess the prey abundance, but without comparing with the adjacent Bardia National Park. Thus, this study is the first attempt to analyse the prey-base situation of tiger in Khata corridor by comparing it with the prey situation in the adjacent park.

LIMITATION OF THE STUDY

The vegetation in riverine forest made difficulty in sampling along the transects in both study areas. So some plots in the park and the some length of transects in the corridor had to be abandoned.

STUDY AREA

South-west corner of Bardia National Park (henceforth referred to as park)

The Bardia National Park (28°15' to 28°35.5' N and 80°10' to 81°45' E) is located in southwest Nepal comprise an area of 986 km^2. The south-west corner of the park is bordered by the large Geruwa River in the west, the East-West highway in the north, and by human settlements and cultivated land in the east and south. The study area in south-west corner covers an area of 29 km^2 (Figure 2).

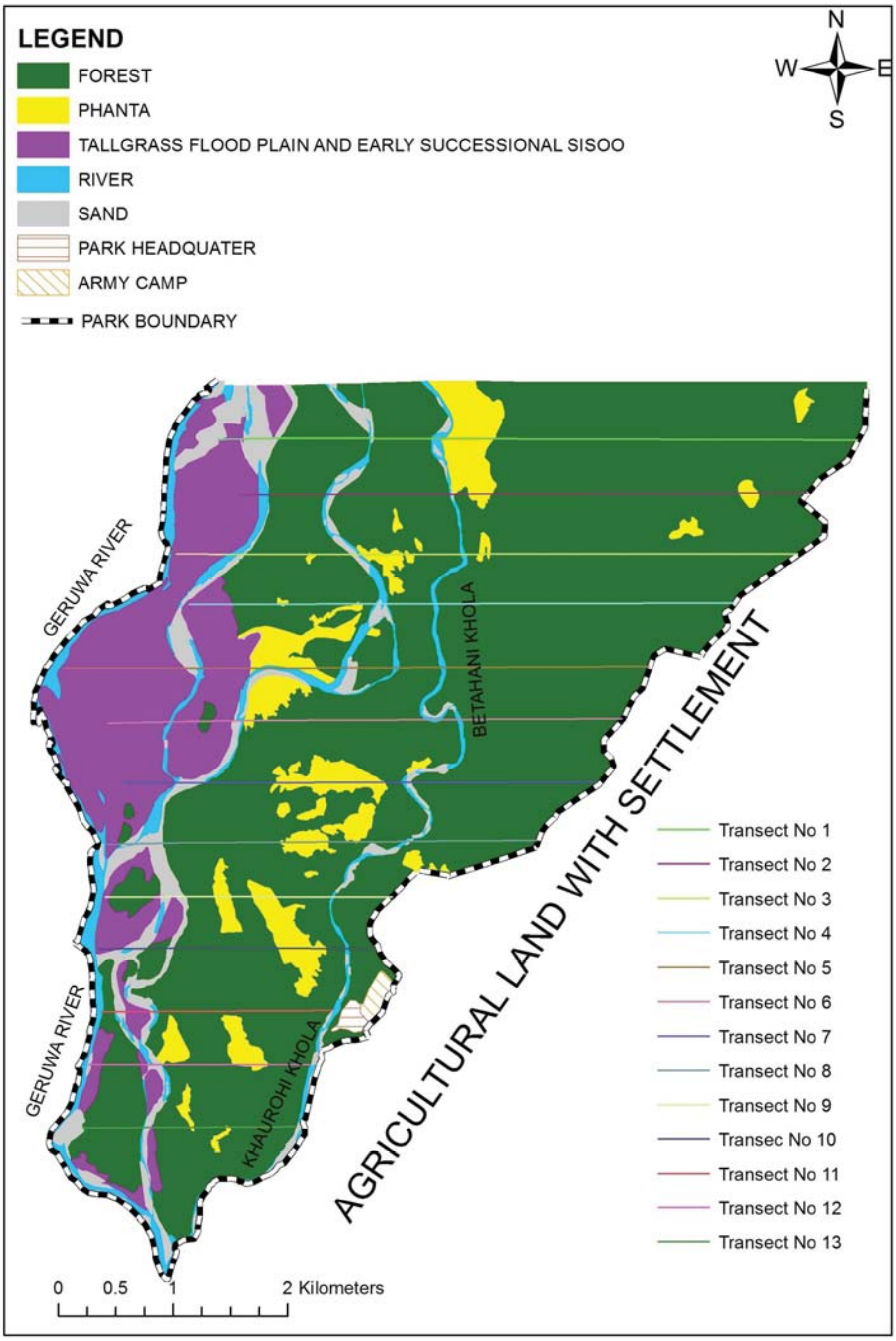

Figure 2. South-west corner of Bardia National Park with study transects

The climate is subtropical monsoonal type. Climatic data from the nearest meteorological station (Chisapani) show that March to June are the hottest months of the year (Figure 3) and November to February the coldest months of the year (Figure 4). July to October represent the monsoon season (Figure 5).

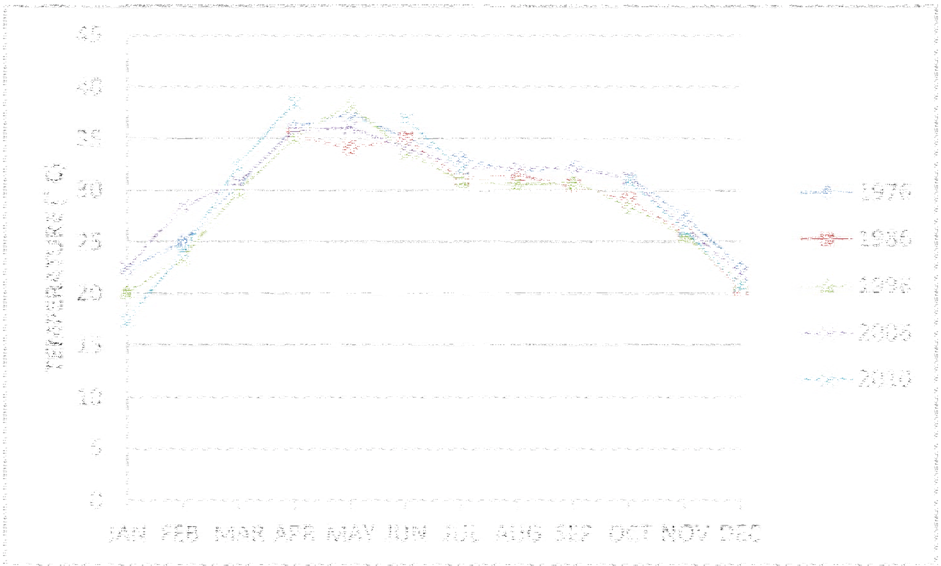

Figure 3. Monthly maximum temperatures of Chisapani (Karnali) for the years 1976, 1986, 1996, 2006 and 2010

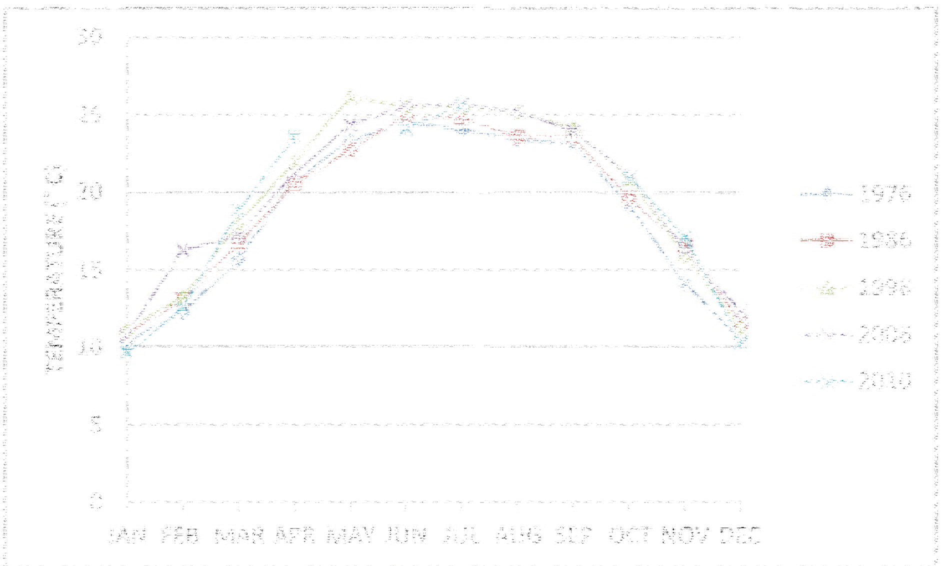

Figure 4. Monthly minimum temperatures of Chisapani (Karnali) for the years 1976, 1986, 1996, 2006 and 2010

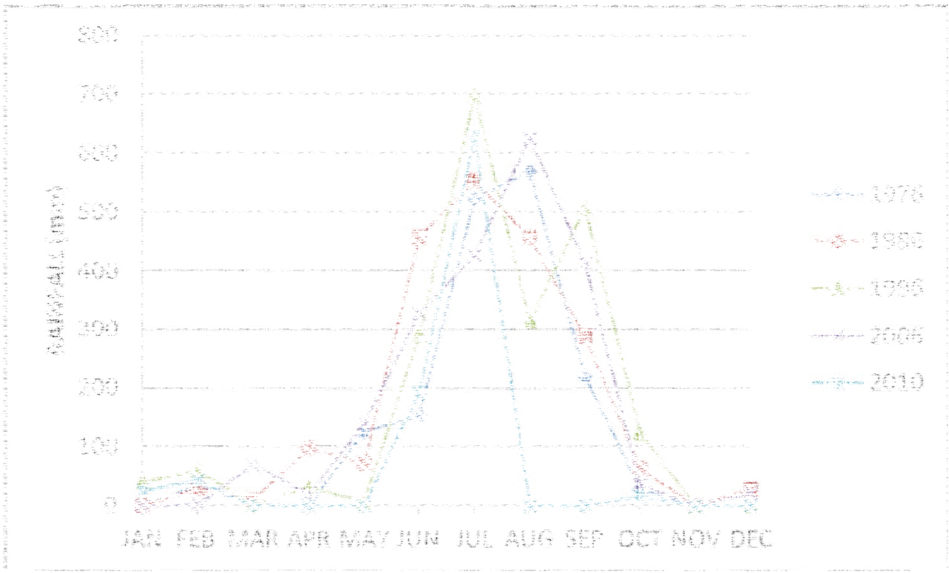

Figure 5. Monthly rainfall for Chisapani (Karnali) in the years 1976, 1986, 1996, 2006 and 2010

The vegetation in the south-west part of the Bardia National Park has been studied by Dinerstein (1979), Jnawali (1995), Jnawali & Wegge (1993), and Sharma (1999). According to Jnawali & Wegge (1993), the major habitats in the area can be classified into 7 types – (a) **Tallgrass floodplain,** dominated by *Saccharum spontaneum* with other tall grass species such as *Saccharum bengalensis, Narenga porphyrocoma, Phragmites karka and shrub species like Callicarpa macrophylla, (b)* Early successional stages of **Khair (*Acacia catechu*) - Sissoo *(Dalbergia sissoo)* forest,** (c) **Riverine forest,** dominated by *Mallotus phillippinensis* and *Syzigium cumini, (d)* **Mixed hardwood** forest, consisting of *Mallotus phillippinensis, Bombax ceiba, Ficus glomerata* and *Eugenia jambolana,*(e) **Sal forest,** dominated by *Shorea robusta* and *Buchhania latifolia,.* (f) **Phanta,** composed of short grass species like *Imperata cylindrica ,* and *Vetiveria zizanoides and* (g) **Bushy pasture (henceforth referred to as degraded scrub),** dominated by grazing and fire-resistant shrubs on previous grazing land near settlements.

Bardia National Park contain at least 53 species of mammal, 400 species of bird, 25 species of reptiles and amphibians and 121 species of fish (RBNP 2005; Upadhyay 2005). The fauna includes a dense population of tiger and leopard (*Panthera pardus*) and their prey like chital, hog deer, wild boar, barking deer, swamp deer and nilgai (Wegge et al. 2009). Other carnivores such as sloth bear (*Melursus ursinus*), jackal (*Canis aureus*) and dhole are also present, but in low numbers (Støen & Wegge 1996). About one decade ago, the tiger population was among the densest in the world, estimated at 13.3 ± 2.08 animals/100km^2, and leopard is common along the park boundary (Wegge et al. 2009).

Bardia-Katarniaghat (Khata) corridor (henceforth referred to as corridor)

Bardia- Katarniaghat (28°27.342' N - 81°12.591' E and 28°22.19' N - 81°13.605' E) is a north-south corridor about 9 km long connecting Bardia National Park with Katarniaghat Wildlife Sanctuary in India (Figure 6). It is dissected by Geruwa and Orai rivers on north-western part, while by Babai river on south-eastern part.

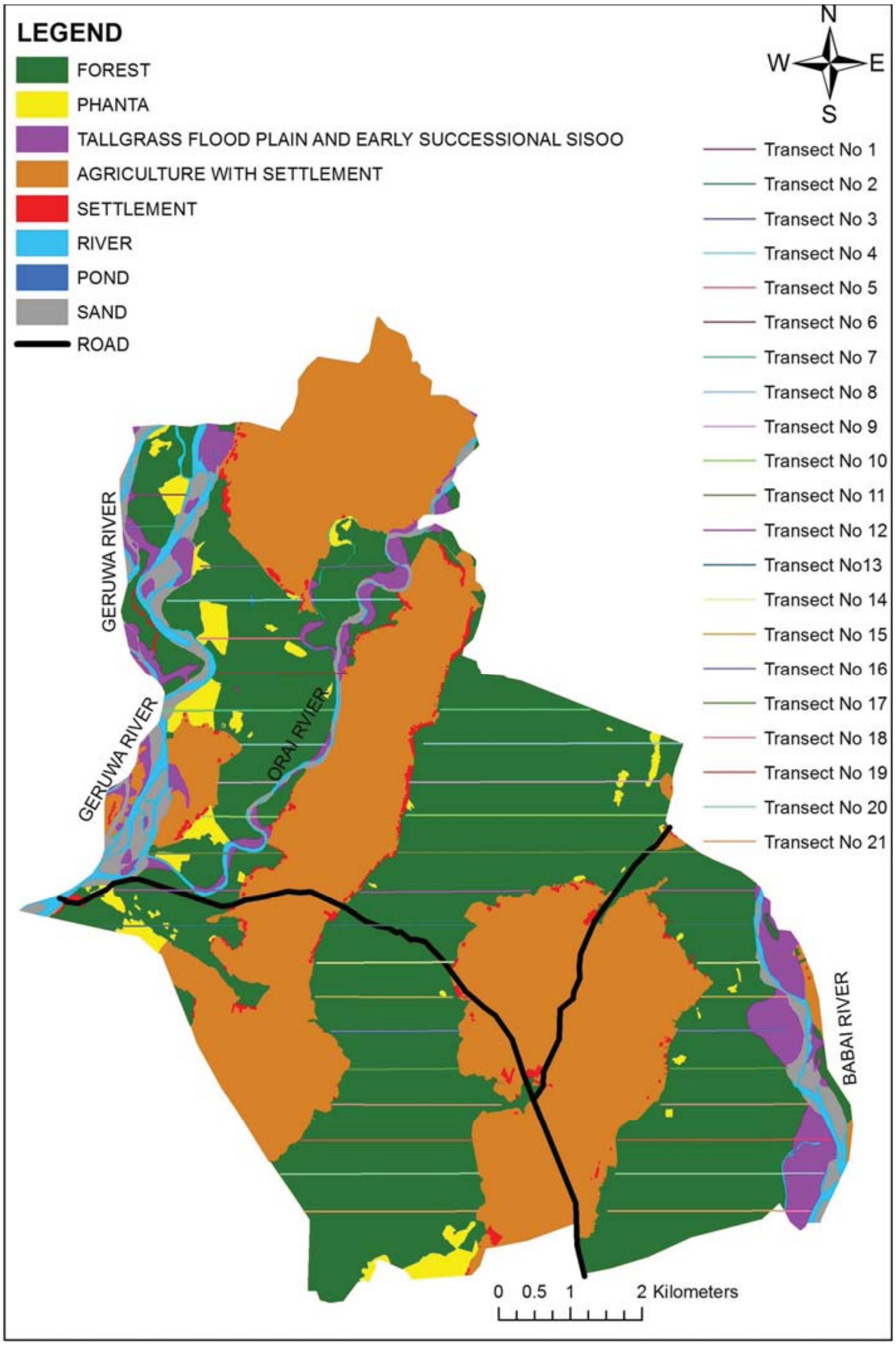

Figure 6. Map of Bardia-Katarniaghat corridor with study transects

It covers an area of approximately 83 km^2 constituting two Village Development Committees namely Surya Patuwa and Dhodhari. Climate data from the nearest meteorological station (Rani Jaruwa Nursery) show that April, May and June are the hottest months (Figure 7) and December, January and February the coldest (Figure 8)

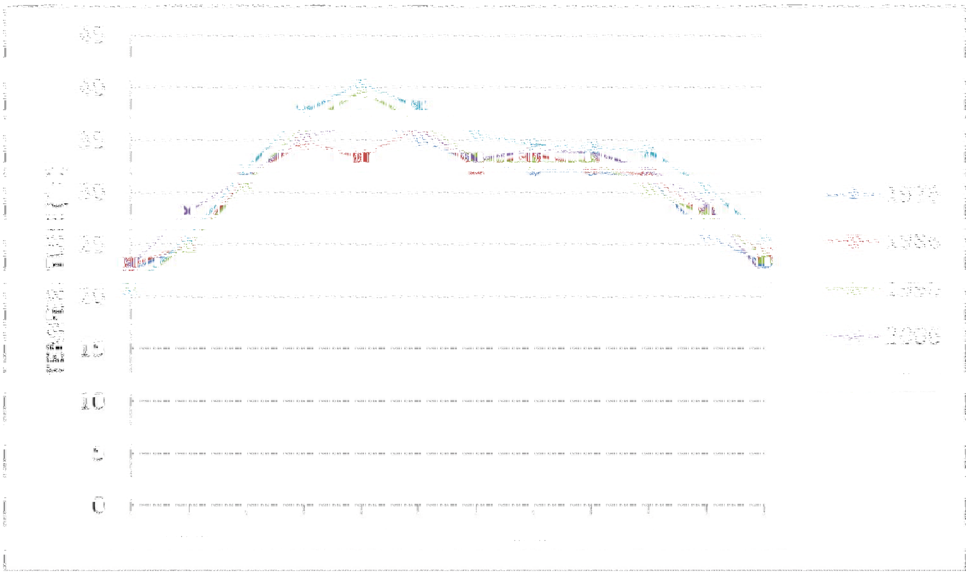

Figure 7. Monthly maximum temperatures of Rani Jaruwa Nursery for the years 1976, 1986, 1996, 2006 and 2010

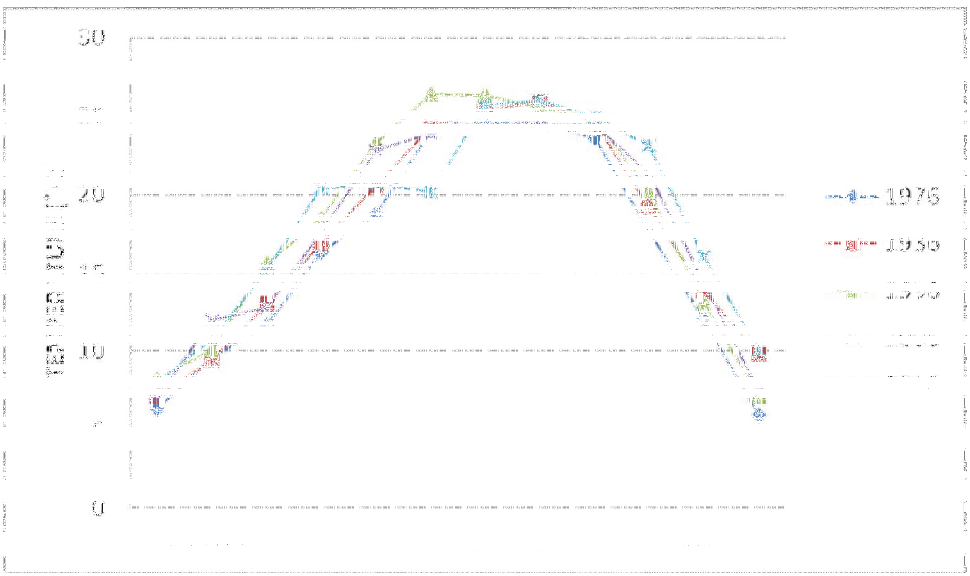

Figure 8. Monthly minimum temperatures of Rani Jaruwa Nursery for the years 1976, 1986, 1996, 2006 and 2010

The area receives the highest rainfall between June-September (Figure 9).

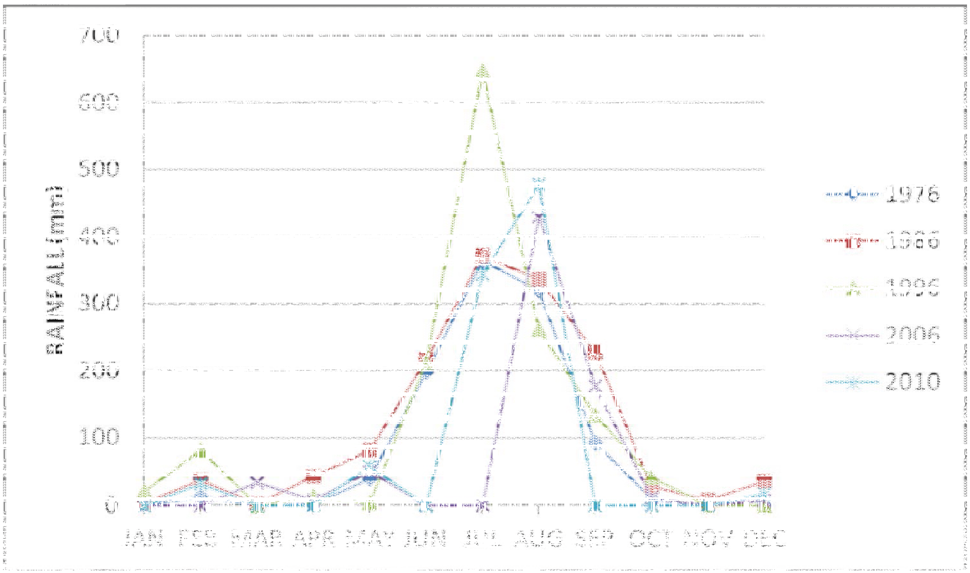

Figure 9. Monthly rainfall for Rani Jaruwa Nursery in the years 1976, 1986, 1996, 2006 and 2010

The vegetation composition of Khata corridor is similar to south-west corner of Bardia National Park except mixed forest. In Khata corridor, most of the part is covered by mixed forests which were riverine and Sal forest in the past. These pure stands forests were degraded by people to present state mixed forest as indicated by species composition. The other habitats include sal forest, riverine forest, early successional Khair - Sissoo forest, phanta, tallgrass floodplain and degraded scrub or bushy pasture. The components of these habitats were similar to south-west corner. The species association in mixed forest varied with the location. However, principal species were *Bombax ceiba*, *M. phillippinensis*, *A. catechu*, *Aegle marmelos*, *S. robusta, Carthamus tinctorius*, *Murraya koenigii*, *Terminalia alata*, *Albizia lebbeck* and *Cassia fistula*. The Geruwa river corridor contained an island with riverine forest with patches of phanta, and tallgrass floodplain in the west. The Orai river corridor was also dominated by riverine forest with highly scattered phanta, tallgrass flood plain in east and west, and old Khair -Sissoo plantation in the north. The Babai river corridor is dominated by mixed forest mostly Sal. Pure stands of Sal also occupied significant area on southern part with few patches of phanta scattered all over. The major portion of tallgrass floodplain and early succesional Sissoo of the corridor was located in the eastern part of the Babai river corridor. There were also small areas of new Sissoo plantations all over the Khata corridor. The main species of plantation included Khair, Sissoo, Simal (*Bombax ceiba*), Teak (*Tectona grandis*) etc.

The corridor is habitat for a few semi-resident rhino (*Rhinoceros unicornis*), Asian wild elephant and tiger (Yadav 2011). Other species include leopard large Indian civet (*Viverra zibetha*), leopard cat (*Felis bengalensis*), jungle cat (*Felis chaus*), binturong (*Arctictis binturong*), small Indian civet (*Viverricula indica*), wild boar, barking deer, chital, hog deer, nilgai, langur, rabbit (*Lepus nigricollis*), (Adhikari & Khadka 2009; Yadav 2011). It also contains 141 bird species, including globally threatened birds like the painted stork (*Mycteria leucocephala*) (Chaudhari et al. 2009). Nearest settlements are Dalla, Naurangha, Bhajpur, Dandagaun, Patharbhoji, Manaughat and Khata to the Geruwa River, comprising communities of indigenous Tharus and hill migrants from Pyuthan, Jumla, Mugu and Kalikot.

METHODOLOGY

Sampling and data collection: This study was conducted from18 October to 7 November in south-west corner of Bardia National Park and from 21 October to 26 November in Khata corridor. Reconnaissance survey was carried out from 15 to 17 October 2011 for collecting reference knowledge on habitat types and pellet groups of different. The line-plot pellet count technique adopted by Wegge (1976) was followed to assess the composition and abundance of tiger prey. Five hundred and eighty eight circular plots of 10 m^2 each were located along 13 line transects 500 m apart at an interval of 50 m in the south-west corner of Bardia National Park (Figure 2). The transects in this area ranged from 1.8 km to 5.0 km (Total = 44.3 km) which will be laid randomly. Similarly, 1221 circular plots were placed along 21 line transects ranging from 0.7 km to 6.7 km (Total = 77 Km) in the Khata corridor (Figure 6).

The sampling was carried on foot. Field sampling was alternated between two study areas to correct the error of accumulation of prey pellets i.e. sampling in another study area after sampling few transects in one study area. In each circular plot, pellets groups, latrines or diggings of prey animals and domestic livestock were recorded. The evidences were noted even if one or two pellets fall on the plot. On finding one or more prey evidences, these were identified and the species was tallied as 'present'. In this case, the number of pellet groups or dungs was not recorded while species were noted separately. For latrine species like barking deer and nilgai, evidences were also searched within distance of 1 m from the transect line on each side. Ground vegetation was separated for searching the plot. Plots falling on sites such as streams, permanent foot trails or cart roads and exposed river beds were avoided.

Data analysis

Habitat composition: Habitat composition in the park and the corridor was determined on the basis of proportional length of different habitats along transects. Graphs for the habitat composition were prepared using Microsoft Excel (2007). Similarly, comparative study on habitat composition of two study areas was done graphical using Sigmaplot v.11.0 (SSI 2008) and significance was tested by Wilcoxon rank sum test using R v.2.14.2 (RDCT 2012).

Tiger prey abundance: The result was expressed as percent abundance for non-latrine species like swamp deer, chital, hog deer, wild boar, sambar deer and livestock as:

$$\textbf{Relative abundance (RA)} = \frac{\underline{\textbf{Plots with present pellet groups}}}{\textbf{Total number of plots}} \times 100$$

For the latrine species barking deer and nilgai, relative abundance was calculated as follows:

$$\textbf{Relative abundance (RA)} = \frac{\underline{\textbf{Plots with present evidences}}}{\textbf{Area in hectare}} \times 100$$

The data was analysed using Fisher's exact test and canonical correspondence analysis (CCA) using the computer program R v.2.14.2 (RDCT 2012). CCA was performed by plotting the relative abundance of prey species against log of percentage transect length in different habitat types. The resultant ordination diagram was triplot with species and transects displayed in blue and red spots against habitat vectors as grey arrows. The proximity of the spots and arrows shows the relationship between the two.

***Habitat cover and land use study*:** Habitat cover for south-west corner of Bardia National Park was determined from Google Earth map of 2012 using ILWIS v.3.31 (Koolhoven et al. 2007) and ArcMap v.10.0 (ESRI 2010). Topographic map of 1997 (scale 1: 25000) of Khata corridor was used in addition to examine land use changes in the area from 1997 to 2011. Land use changes in Khata corridor was estimated in terms of change in the areas of forest, phanta, tallgrass floodplain and early successional Sissoo, agricultural land with settlement and river from 1997 to 2011. Similarly, distribution maps of tiger prey species.

***Use of environmental variables in data analysis*:** The habitat classification, modified from Jnawali and Wegge (1993) and Wegge & Storaas (2009) was followed for data analysis which includes- Sal forest, riverine forest, phanta, tallgrass floodplain and early successional Sissoo and degraded scrubland. In the Khata corridor, mixed forest and secondary forest were added for indicating forest consisting of mixed tree species and plantation forest areas respectively.

RESULTS

Habitat composition

The habitat composition in the park and the corridor are shown in figures 10 and 11, respectively. In the park, riverine forest occupied most of the area (44.5%) followed by Sal forest, tallgrass floodplain and early succession Sissoo, and phanta. Contrastingly, mixed forest was the most extensive habitat (53.8%) in the corridor.

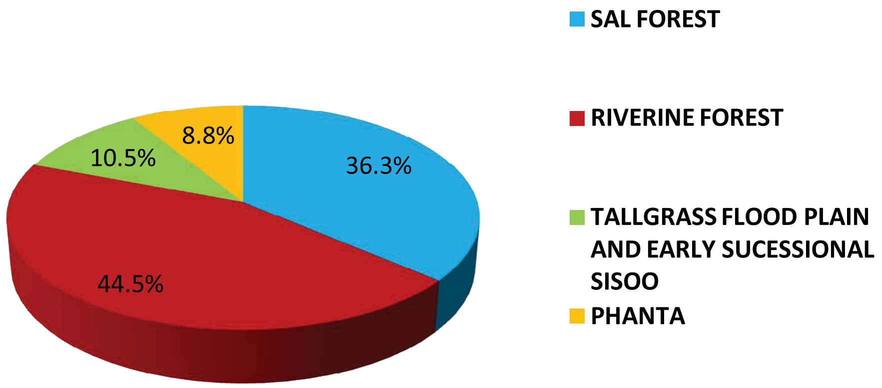

Figure 10. Habitat composition (based on proportional lengths of habitats along transects) in the park

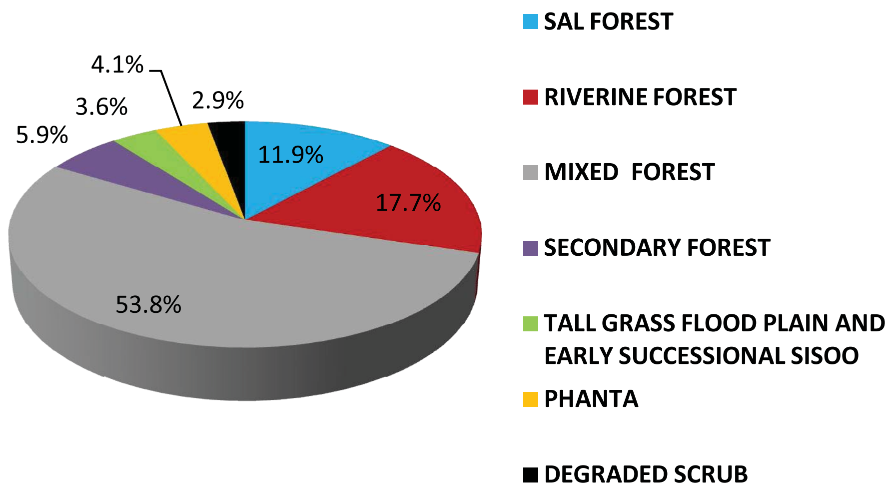

Figure 11. Habitat composition (based on proportional lengths of habitats along transects) in the corridor

However, the proportions of Sal forest, riverine forest, phanta and tallgrass floodplain were distinctively higher in the park than in the corridor (Figure 12). Secondary forest, degraded scrub and mixed forest only occurred in the corridor.

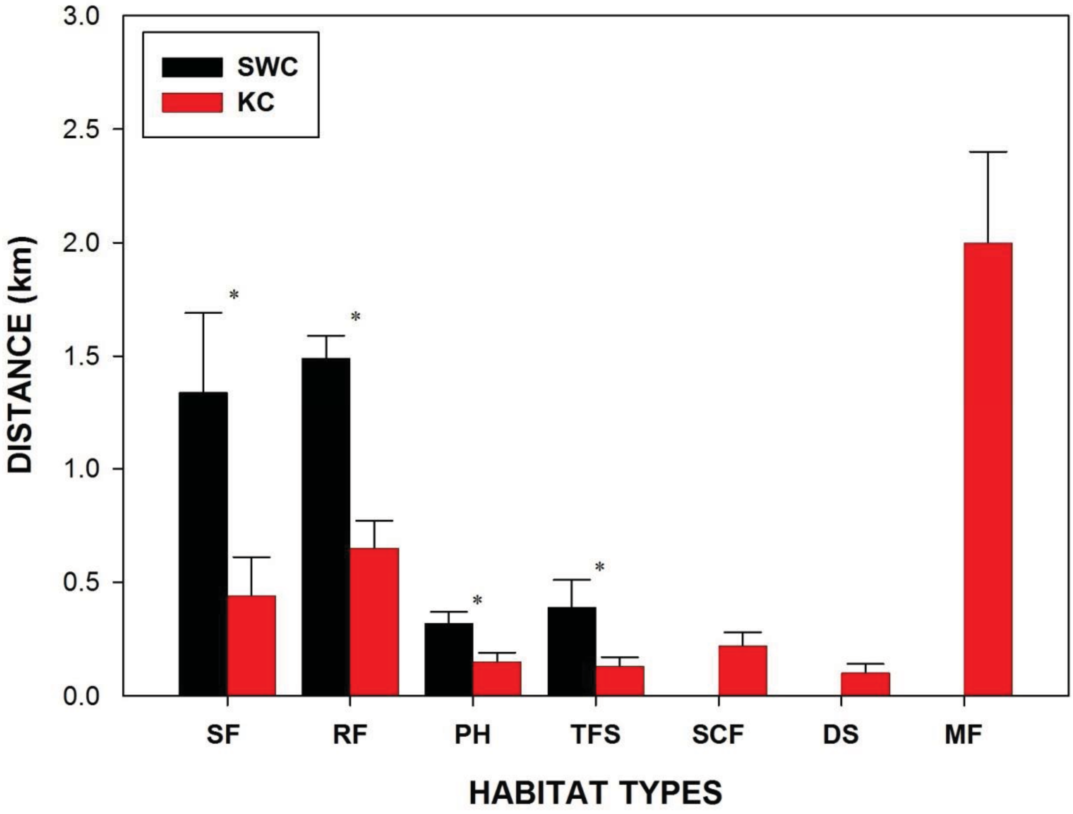

Figure 12. Comparison of habitat composition between the south-west corner of Bardia National Park (SWC) and Khata corridor (KC). SF = Sal forest, RF = Riverine forest, PH = Phanta, TFS = Tallgrass floodplain and early successional Sissoo, DS = Degraded scrub and MHF = Mixed hardwood forest, ┬ = Standard error, * = p ≤ 0.05 (Wilcoxon rank sum p-value).

Tiger prey base abundance

Major tiger prey species such as chital and hog deer had significantly higher abundance in the park than in the corridor (Table 1). Wild boar was distinctively most abundant in the corridor than in the park. Swamp deer and sambar deer pellet groups were recorded only in the park. Livestock pellet groups were observed in 14.3% of plots only in the corridor. Among latrine species, the results showed that barking deer had higher abundance in the park than in the corridor, but nilgai had higher abundance in the corridor than in the park.

Table 1. Comparison of tiger prey abundance between south-west corner of Bardia National Park (SWC) and Bardia-Katarniaghat corridor (KC)

SPECIES	SCIENTIFIC NAME	RELATIVE ABUNDANCE (RA)[a] SWC	KC	P-VALUE
Swamp Deer	*Cervus duvauceli*	3.1	0.0	≤ 0.001
Chital	*Axis axis*	45.7	4.6	≤ 0.001
Hog Deer	*Axis porcinus*	10.2	1.5	≤ 0.001
Sambar Deer	*Cervus unicolor*	0.2	0.0	0.325
Livestock		0.0	14.3	≤ 0.001
Wild Boar	*Sus scrofa*	22.8[b]	35.6[b]	≤ 0.001
Barking Deer	*Muntiacus muntjac*	1.7[c]	1.4[c]	NA
Nilgai	*Boselaphus tragocamelus*	0.2[c]	1.1[c]	NA

a = Plots with present pellet groups/Total number of plots x 100
b = Plots with present diggings/Total number of plots x 100
c = Total number of evidences/Area in hectare
NA = Not available

Habitat specific tiger prey base abundance

***Sal forest*:** In Sal forest, chital was most abundant in the park than in the corridor whereas wild boar was most abundant in the corridor than in the park (Table 2). The only observed pellet group of sambar deer was found in Sal forest plot of the park. Chital pellet groups were not found in the corridor. The results found that both barking deer and nilgai had higher abundance in the corridor than in the park.

Table 2. Comparison of tiger prey abundance between Sal forest of south-west corner of Bardia National Park (SWC) and Bardia-Katarniaghat corridor (KC)

SPECIES	SCIENTIFIC NAME	RELATIVE ABUNDANCE (RA)[a] SWC	KC	P-VALUE
Swamp Deer	*Cervus duvauceli*	0.0	0.0	NA
Chital	*Axis axis*	43.9	0.0	≤ 0.001
Hog Deer	*Axis porcinus*	0.0	0.0	NA
Sambar Deer	*Cervus unicolor*	0.5	0.0	1
Livestock		0.0	9.8	≤ 0.001
Wild Boar	*Sus scrofa*	35.4[b]	50.5[b]	0.004
Barking Deer	*Muntiacus muntjac*	3.1[c]	3.8[c]	NA
Nilgai	*Boselaphus tragocamelus*	0.6[c]	1.1[c]	NA

a = Plots with present pellet groups/Total number of plots x 100
b = Plots with present diggings/Total number of plots x 100
c = Total number of evidences/Area in hectare
NA = Not available

***Riverine forest*:** Chital and hog deer were most abundant in the riverine forest of the park than of the corridor (Table 3). However, there was no significant difference in the abundance of wild boar in both study areas. Nilgai and barking deer pellet groups respectively were not observed in riverine forest plots of the park and the corridor.

Table 3. Comparision of tiger prey abundance between riverine forest of south-west corner of Bardia National Park (SWC) and Bardia-Katarniaghat corridor (KC)

SPECIES	SCIENTIFIC NAME	RELATIVE ABUNDANCE (RA)[a]		P-VALUE
		SWC	KC	
Swamp Deer	*Cervus duvauceli*	3.5	0.0	0.012
Chital	*Axis axis*	51.0	21.2	≤ 0.001
Hog Deer	*Axis porcinus*	7.4	2.1	0.016
Sambar Deer	*Cervus unicolor*	0.0	0.0	NA
Livestock		0.0	2.6	0.013
Wild Boar	*Sus scrofa*	18.7[b]	29.6[b]	0.009
Barking Deer	*Muntiacus muntjac*	1.3[c]	0.0[c]	NA
Nilgai	*Boselaphus tragocamelus*	0.0[c]	2.6[c]	NA

a = Plots with present pellet groups/Total number of plots x 100
b = Plots with present diggings/Total number of plots x 100
c = Total number of evidences/Area in hectare
NA = Not available

***Phanta*:** In the phanta habitat, chital had higher abundance in the park than in the corridor (Table 4). The result found that wild boar diggings were recorded highest in the corridor than in the park. Though, there was no significant difference in the abundance of wild boar in both study areas.

Table 4. Comparison of tiger prey abundance between phanta of south-west corner of Bardia National Park (SWC) and Bardia-Katarniaghat corridor (KC)

SPECIES	SCIENTIFIC NAME	RELATIVE ABUNDANCE (RA)[a]		P-VALUE
		SWC	KC	
Swamp Deer	*Cervus duvauceli*	11.8	0.0	0.011
Chital	*Axis axis*	42.1	8.0	≤ 0.001
Hog Deer	*Axis porcinus*	2.6	0.0	0.518
Sambar Deer	*Cervus unicolor*	0.0	0.0	NA
Livestock		0.0	8.0	0.023
Wild Boar	*Sus scrofa*	9.2[b]	12[b]	0.766
Barking Deer	*Muntiacus muntjac*	0.0[c]	1.6[c]	NA
Nilgai	*Boselaphus tragocamelus*	0	0	NA

a = Plots with present pellet groups/Total number of plots x 100
b = Plots with present diggings/Total number of plots x 100
c = Total number of evidences/Area in hectare
NA = Not available

***Tallgrass floodplain and early successional Sissoo*:** In both study areas, hog deer was the most abundant species in this habitat, with a significantly higher abundance in the park (Table 5). Chital was significantly more abundant in this habitat in the park than in the corridor. The abundance of wild boar was similar in the two study areas. Nilgai latrines were found only in the corridor.

Table 5. Comparison of tiger prey abundance between tallgrass floodplain of south-west corner of Bardia National Park (SWC) and Bardia-Katarniaghat corridor (KC)

SPECIES	SCIENTIFIC NAME	RELATIVE ABUNDANCE (RA)[a]		P-VALUE
		SWC	KC	
Swamp Deer	*Cervus duvauceli*	0.0	0.0	NA
Chital	*Axis axis*	33.3	6.1	≤ 0.001
Hog Deer	*Axis porcinus*	68.4	26.5	≤ 0.001
Sambar Deer	*Cervus unicolor*	0.0	0.0	NA
Livestock		0.0	24.5	≤ 0.001
Wild Boar	*Sus scrofa*	15.8[b]	14.3[b]	1
Barking Deer	*Muntiacus muntjac*	0.0	0.0	NA
Nilgai	*Boselaphus tragocamelus*	0.0[c]	5.4[c]	NA

a = Plots with present pellet groups/Total number of plots x 100
b = Plots with present diggings/Total number of plots x 100
c = Total number of evidences/Area in hectare
NA = Not available

***Mixed hardwood forest, secondary forest and degraded scrub*:** Mixed hardwood forest, secondary forest and degraded scrub were only recorded in the corridor (Table 6). Wild boar was the most abundant wild species in these habitats and the highest abundance was found in mixed hardwood forest. Livestock used these habitats extensively, but was mostly found in degraded scrub. Chital pellet groups were occasionally found in secondary forest and mixed hardwood forest. Barking deer was only found in mixed hardwood forest.

Table 6. Comparison of tiger prey abundance in mixed hardwood forest (MHF), secondary forest (SCF), and degraded scrub (DS) of Bardia-Katarniaghat corridor

SPECIES	SCIENTIFIC NAME	RELATIVE ABUNDANCE (RA)[a]		
		SCF	DS	MHF
Swamp Deer	*Cervus duvauceli*	0.0	0.0	0.0
Chital	*Axis axis*	3.4	0.0	1.1
Hog Deer	*Axis porcinus*	0.0	0.0	0.2
Sambar Deer	*Cervus unicolor*	0.0	0.0	0.0
Livestock		13.8	79.4	15.5
Wild Boar	*Sus scrofa*	15.5[b]	2.9[b]	40.5[b]
Barking Deer	*Muntiacus muntjac*	NA	NA	1.7[c]
Nilgai	*Boselaphus tragocamelus*	NA	NA	0.6[c]

a = Plots with present pellet groups/Total number of plots x 100
b = Plots with present diggings/Total number of plots x 100
c = Total number of evidences/Area in hectare
NA = Not available

Species-specific tiger prey abundance

Chital**:** Chital was evenly distributed across all habitat types in the the park (Figure 13). This is supported by the CCA ordination where Chital is placed very central in the diagram, suggesting an ubiquitous distribution across the different habitat types (Figure 14).

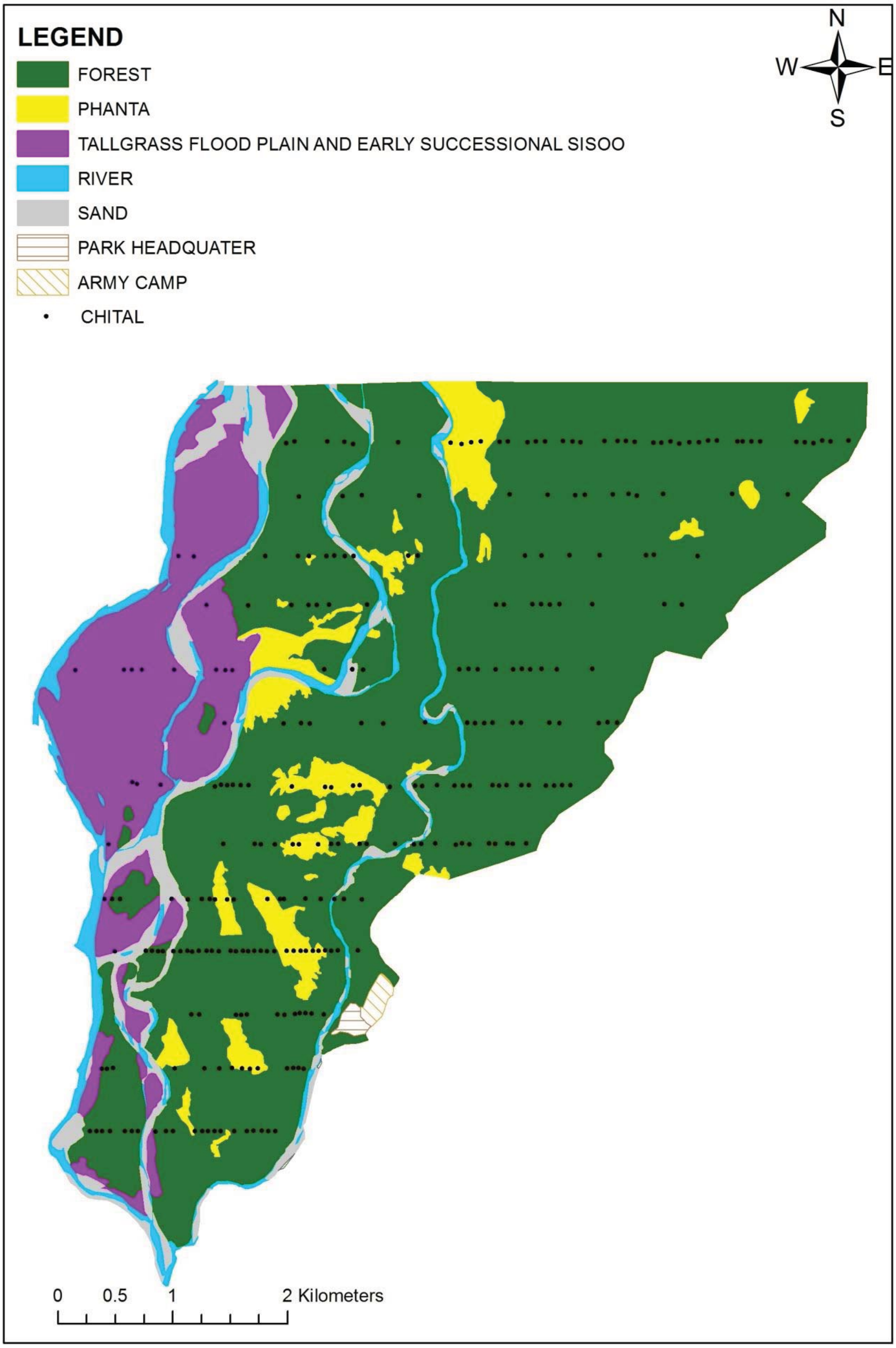

Figure 13. Distribution of chital pellet groups recorded in the south-west corner of Bardia National Park.

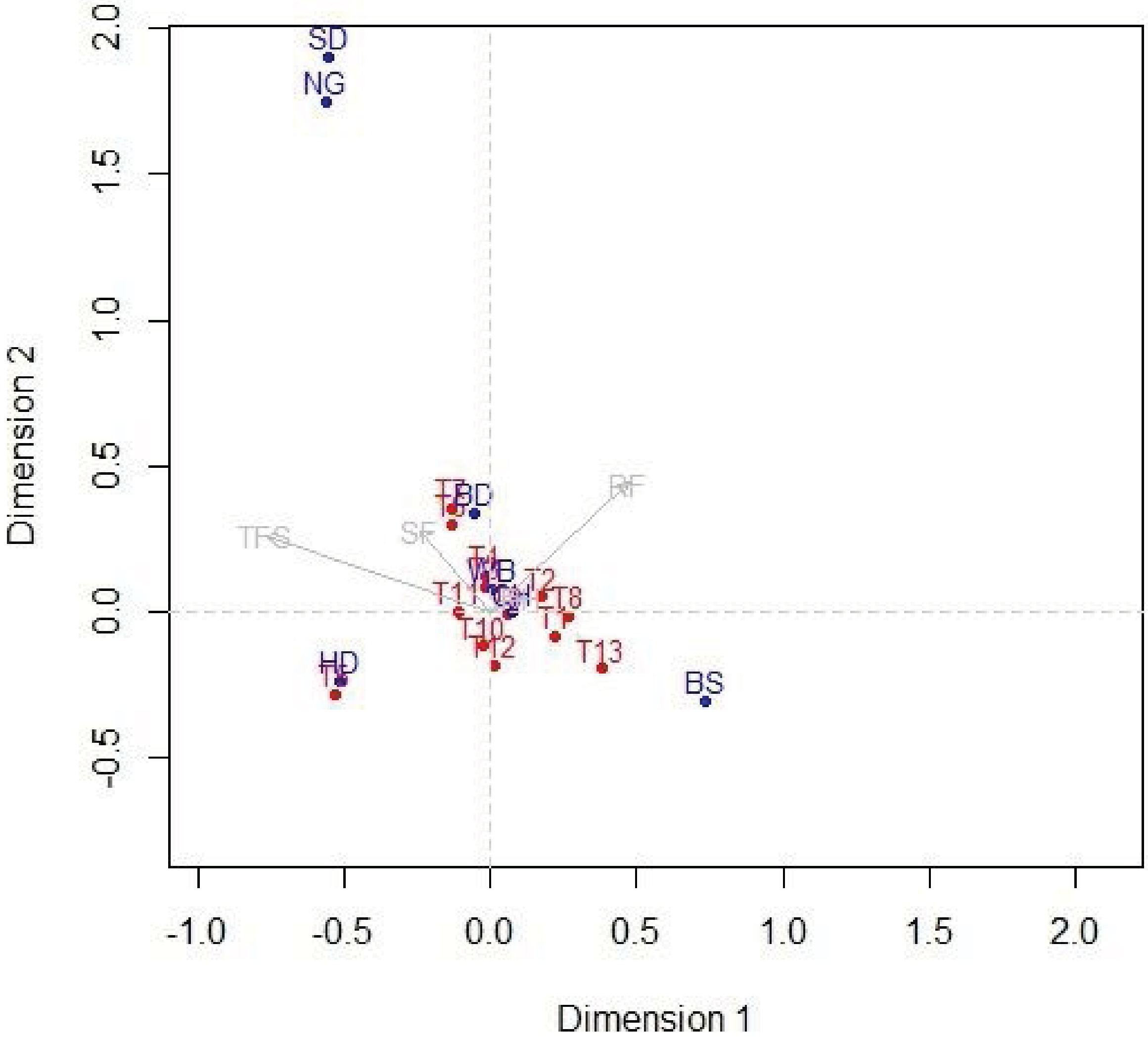

Figure 14. Canonical Correspondence Analysis for south-west corner of Bardia National Park. SF = Sal forest, RF = Riverine forest, PH = Phanta, TFS = Tallgrass floodplain and early successional Sissoo, BS = Barasingha (Swamp deer), CH = Chital, BD = Barking deer, HD = Hog deer, SD = Sambar deer, WB = Wild boar, NG = Nilgai and T(n) = Transect(Number).

In the corridor, Canonical correspondence analysis showed that chital was abundant in the riverine forest (15).

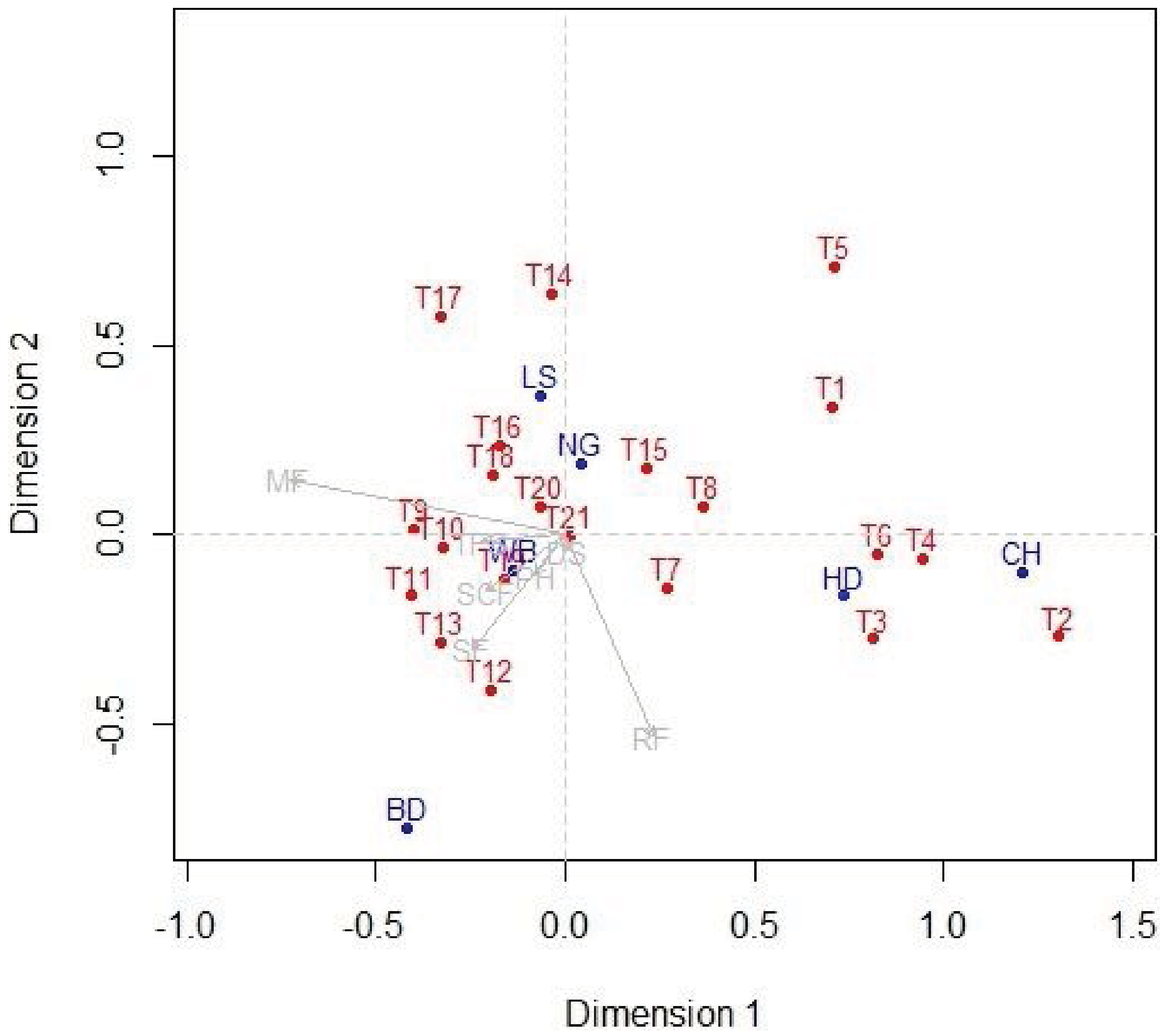

Figure 15. Canonical Correspondence Analysis for Bardia-Katarniaghat Corridor. SF = Sal forest, RF = Riverine forest, MF = Mixed hardwood forest, PH = Phanta, TFS = Tallgrass floodplain and early successional Sissoo, SCF = Secondary forest, DS = Degraded scrub, BS = Barasingha (Swamp deer), CH = Chital, BD = Barking deer, HD = Hog deer, WB = Wild boar, NG = Nilgai, LS = Livestock and T(n) = Transect(Number).

Distribution map also showed most disbursed plots with chital pellets in the area adjacent to Orai river, but with less number of plots in the areas adjacent to Geruwa and Babai rivers (Figure 16).

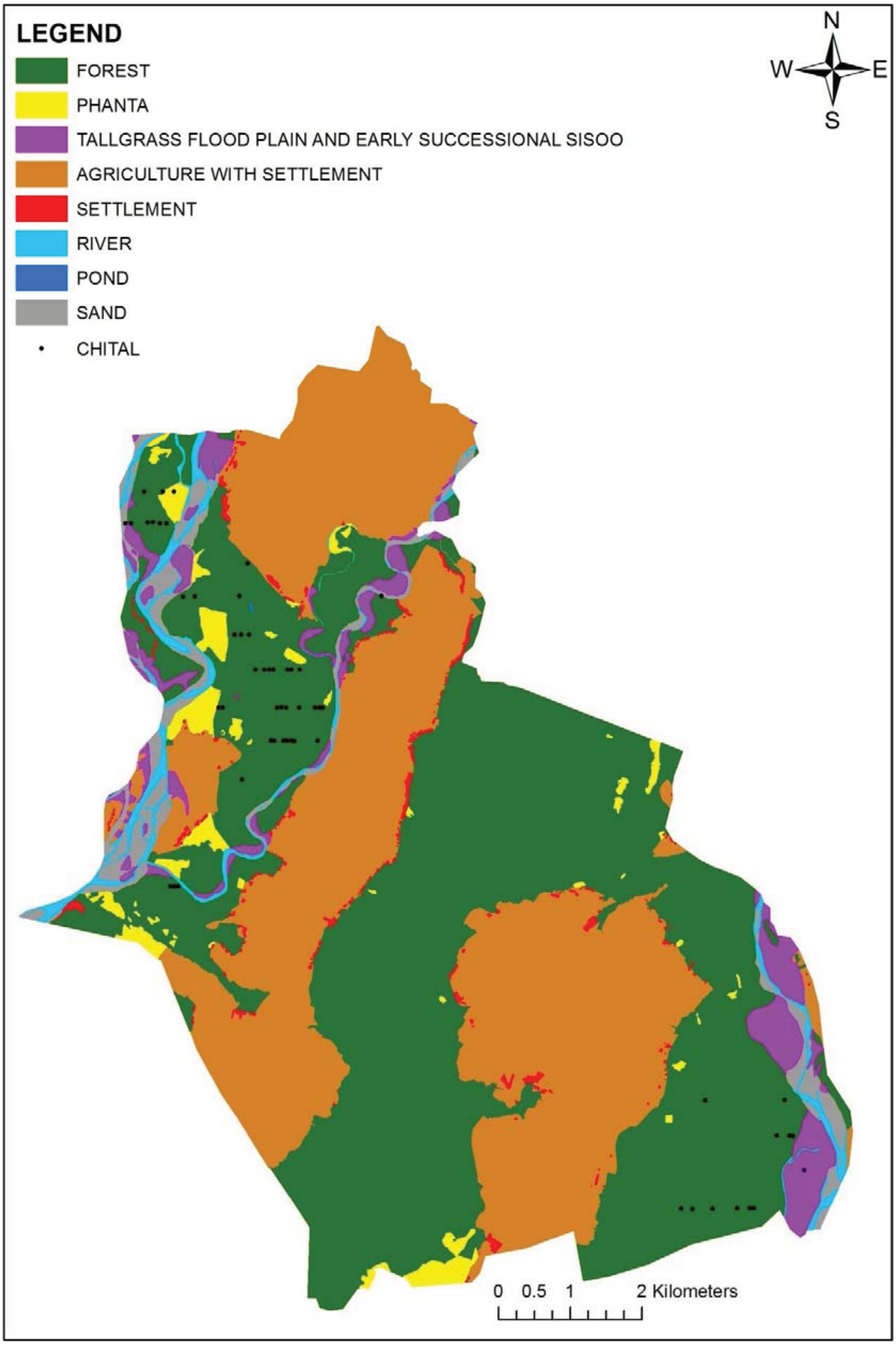

Figure 16. Distribution of chital pellet groups recorded in the Bardia-Katarniaghat corridor

Wild boar: Like chital, wild boar diggings were common across all habitat types in the park (Figure 15), but with higher frequency in the forests near cultivation and settlements in the east. (Figure 17).

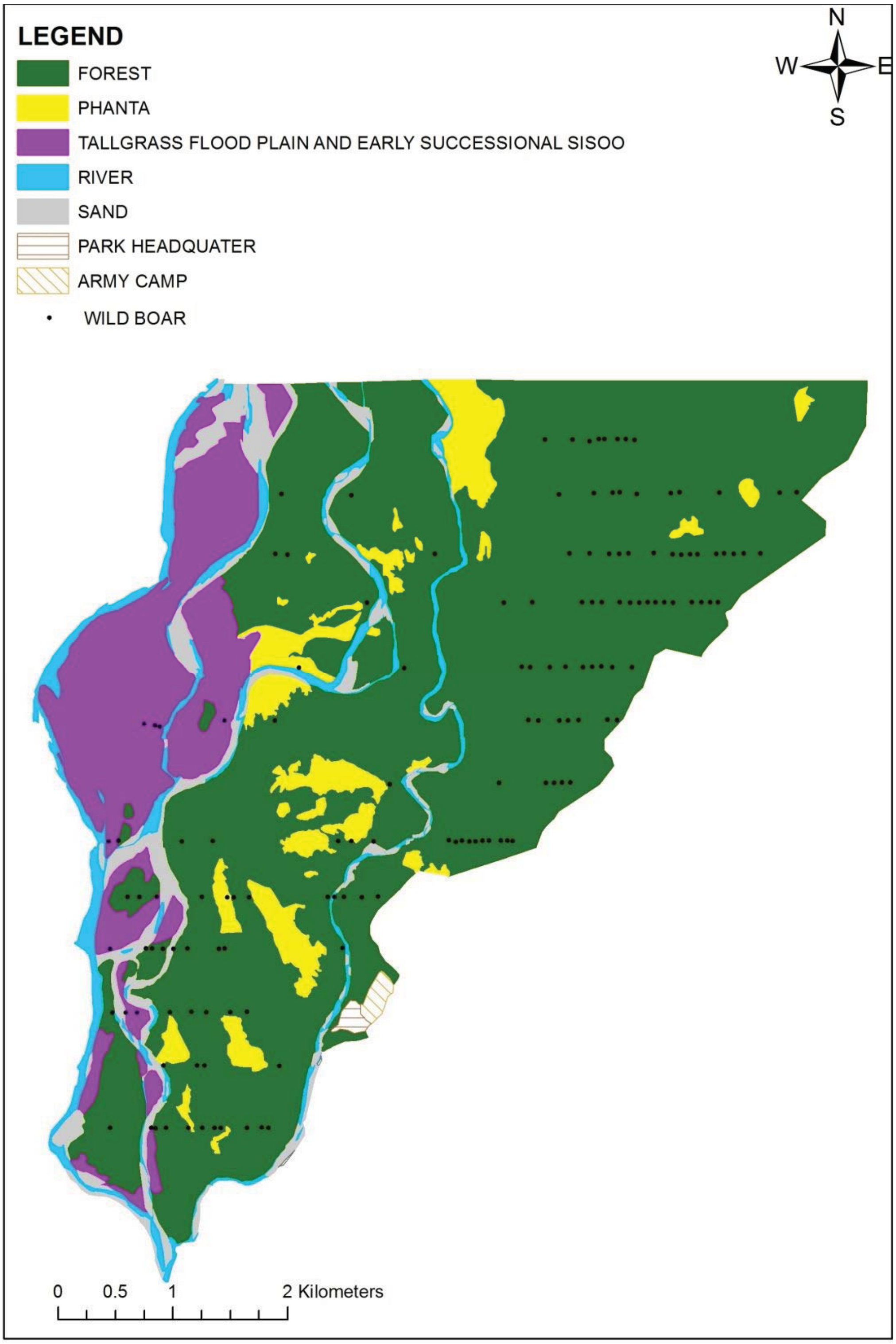

Figure 17. Distribution of wild boar diggings recorded in the south-west corner of Bardia National Park

Wild boar appeared to be abundant across forests in the corridor (Figure 18).

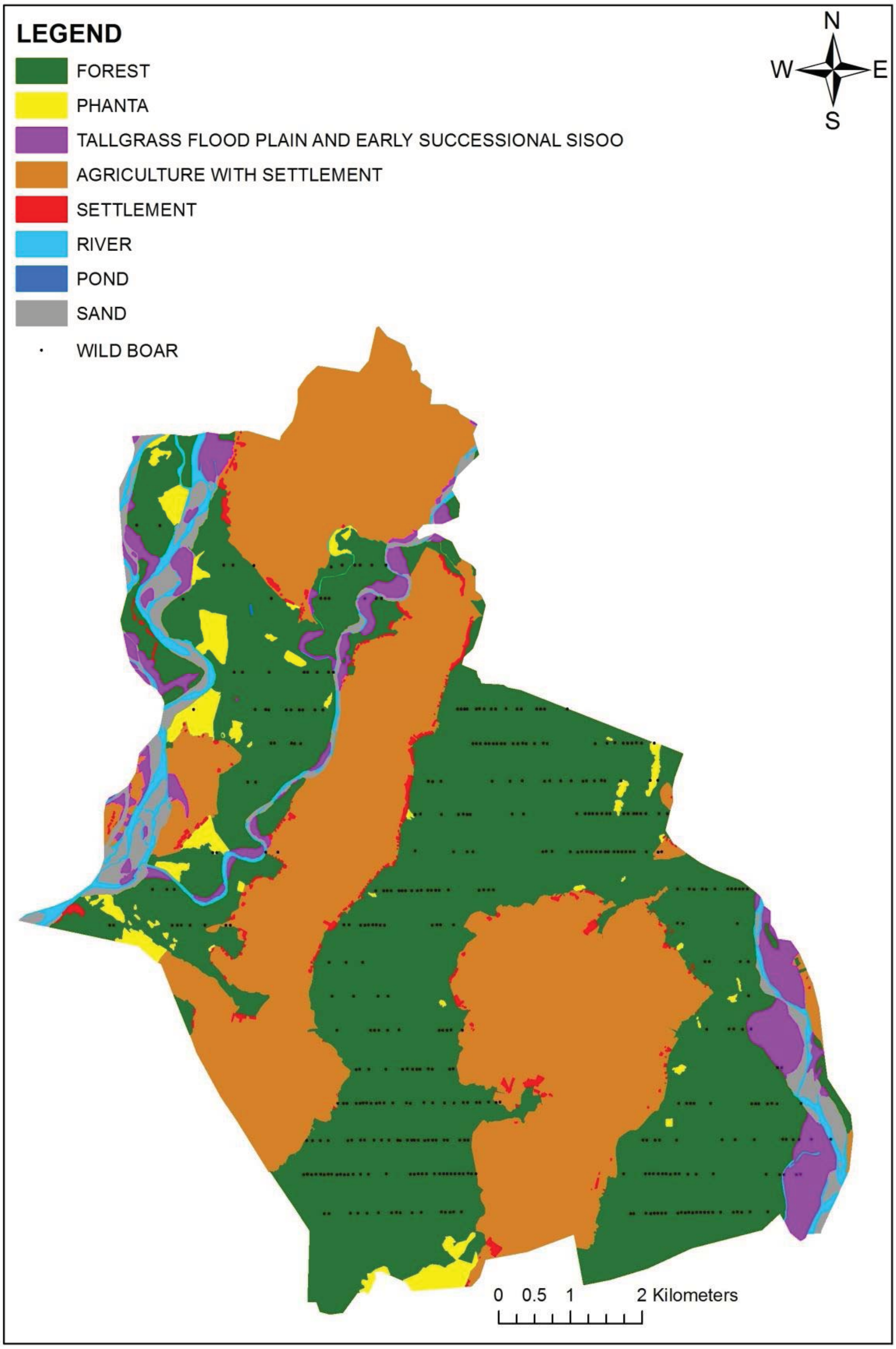

Figure 18. Distribution of wild boar diggings recorded in the Bardia-Katarniaghat corridor

***Hog deer*:** The hog deer was most abundant in tallgrass floodplain, but less abundant in the phanta of the park (Figure 14 & 19).

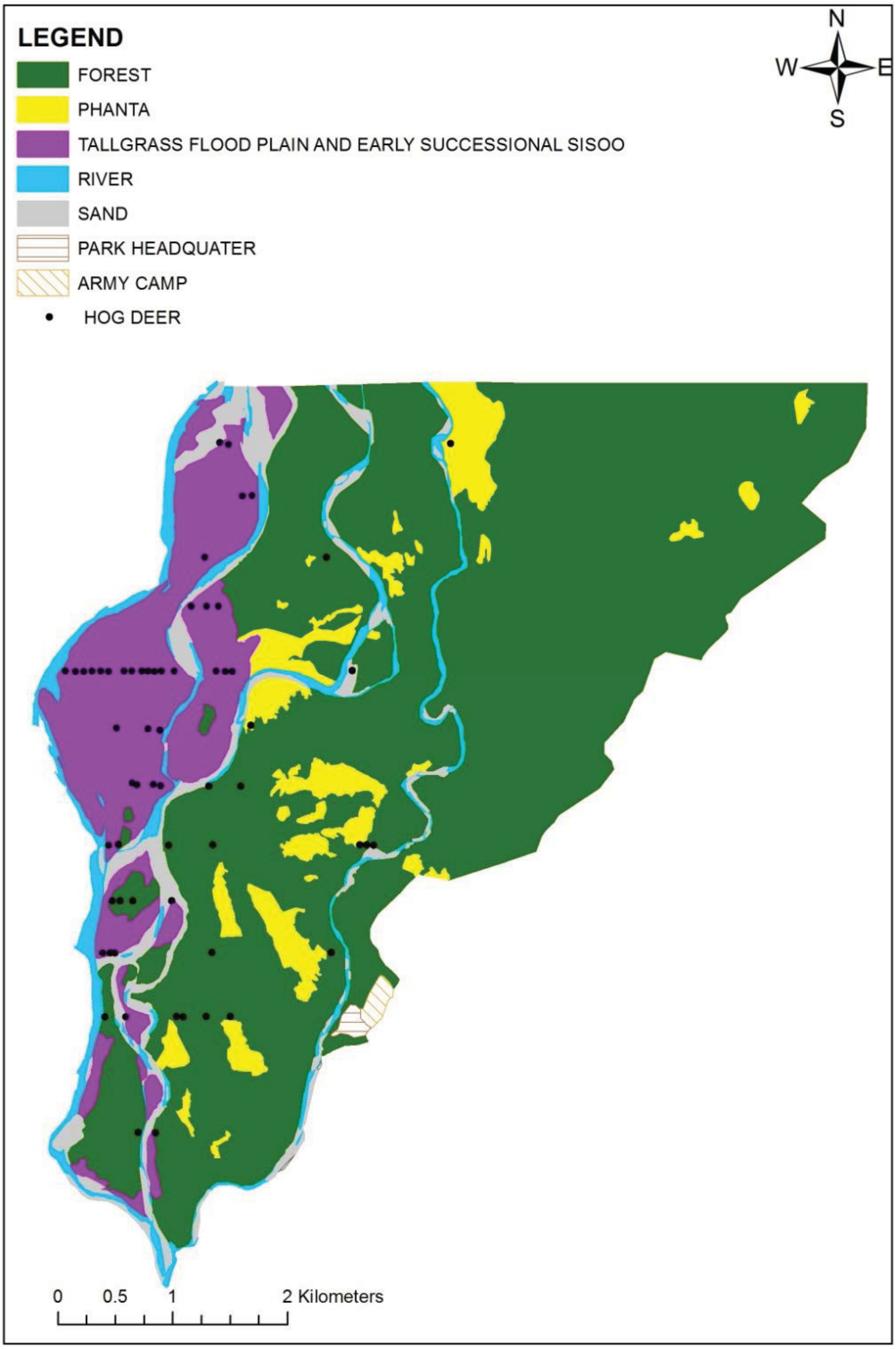

Figure 19. Distibution of hog deer pellet groups recorded in the south-west corner of Bardia National Park

In the corridor, it had higher abundance in tallgrass floodplain (Figure 20), but lower in mixed forest (Figure 15).

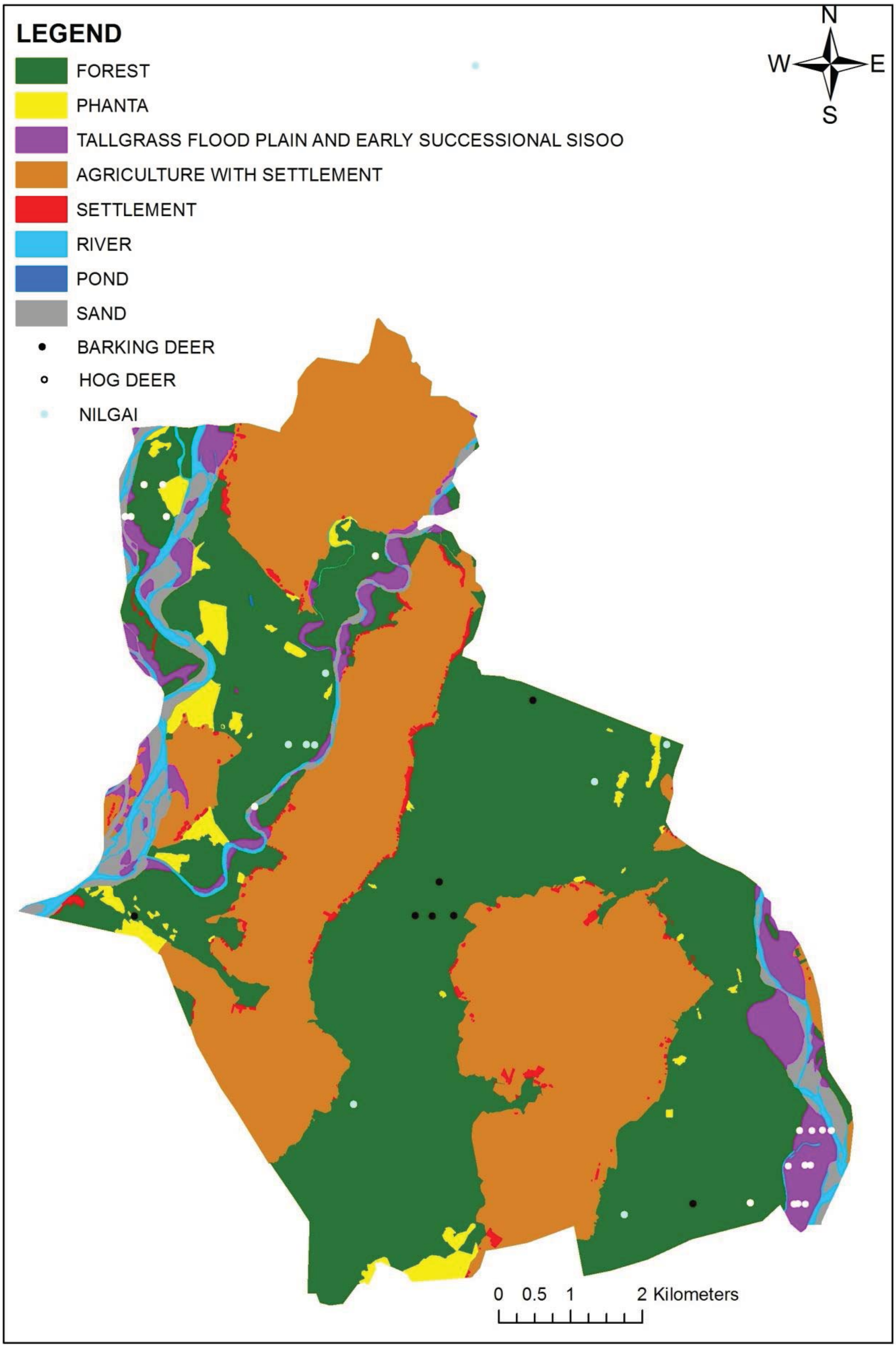

Figure 20. Distribution of pellet groups of barking deer, hog deer and nilgai recorded in the Bardia-Katarniaghat corridor

Swamp deer, sambar deer, nilgai and barking deer: Swamp deer was only present in the park, and was abundant in phanta as revealed by CCA (Figure 14). Sambar deer and nilgai pellets were rare in the park. The distribution of the four species in the park is shown in figure 21. Nilgai was abundant in mixed forest in the corridor (Figure 15). Barking deer was mostly recorded in sal forest of both study areas.

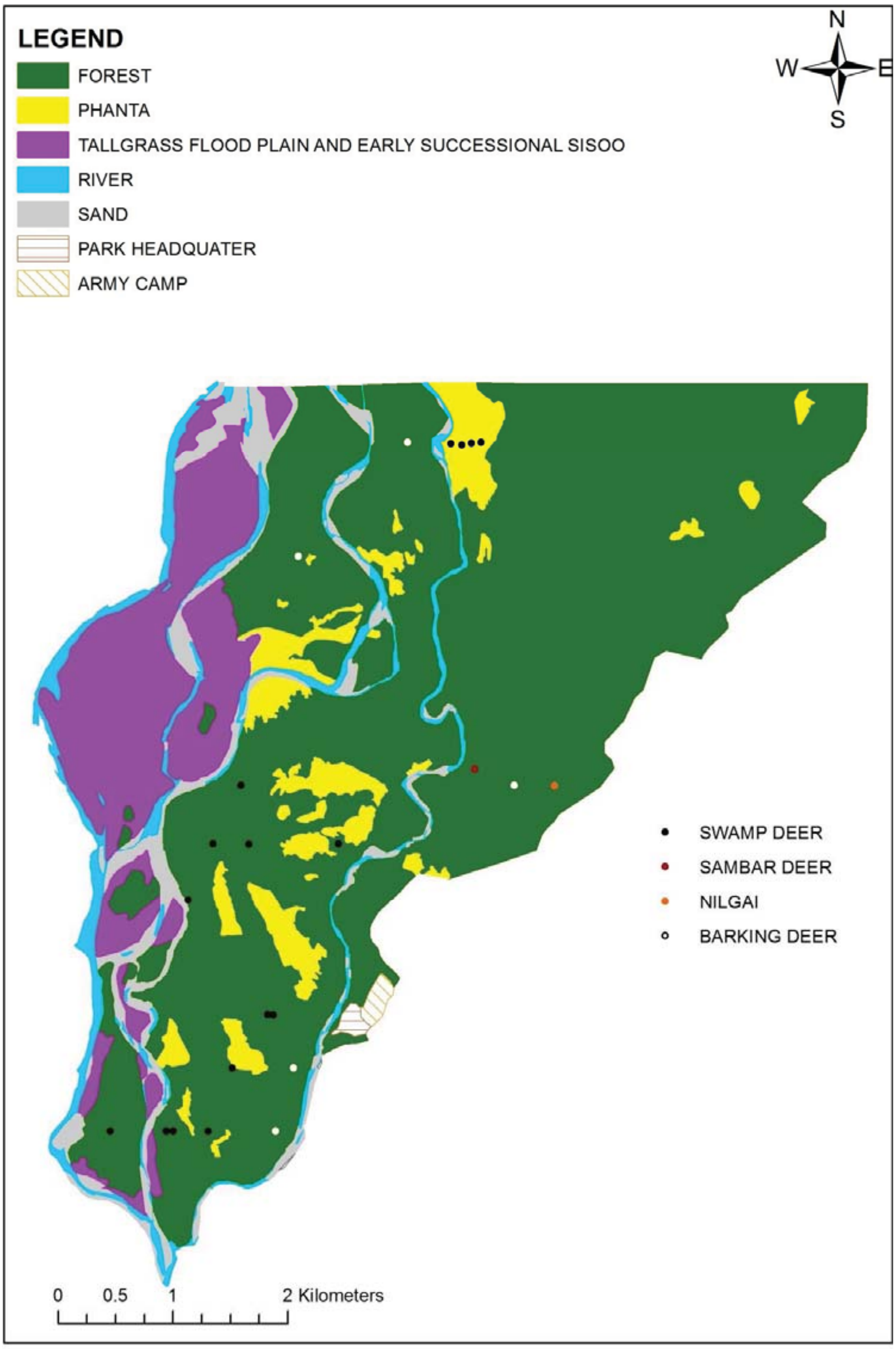

Figure 21. Distribution of pellet groups of swamp deer, sambar deer, nilgai and barking deer recorded in the south-west corner of Bardia National Park

Livestock: With the second highest abundance among all ungulates, livestock pellet groups were only noted in the corridor. Livestock was most abundant in degraded scrub and less abundant in riverine forest, was also supported by the CCA (Figure 15). The distribution of livestock in the corridor is shown in figure which points the higher abundance in middle and western part of the corridor (22).

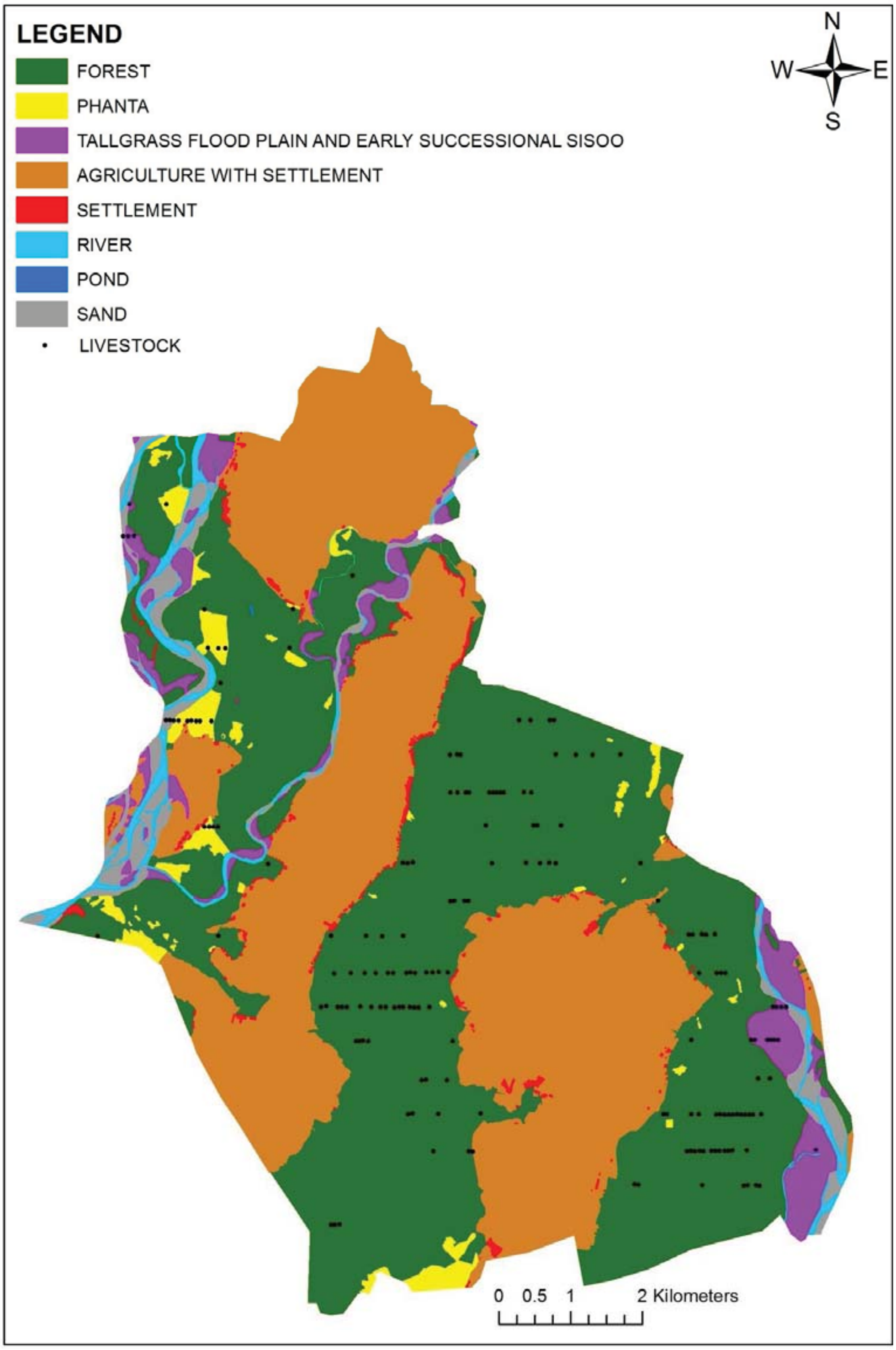

Figure 22. Distribution of livestock pellet groups recorded in the Bardia-Katarniaghat corridor

Changes in habitat cover and land use in the Khata corridor

In 1997, forests dominated the land area in the corridor (49.7%). This was followed by agricultural land with settlement, river, tallgrass floodplain and early successional Sissoo, and phanta (Table 7). Forests also dominated the land area in 2011 (49.6%). There were small and insignificant changes in land cover between 1997 and 2011 (Table 7).

Table 7. Habitat composition of Bardia-Katarniaghat corridor in the 1997 and 2011

LAND TYPES	AREA 1997 (%)	AREA 2011 (%)
Forest	49.7	49.6
Tallgrass flood plain and early successional Sissoo	3.5	4.0
Phanta	1.7	2.2
Agriculture with settlement	37.6	39.0
River	7.5	5.2

DISCUSSION

Among major tiger prey species, chital had ten times higher abundance in the park than in the corridor. Dinerstein (1979b) and Moe & Wegge (1994) found that chital preferred phanta most among all habitat types. Although known to be mixed feeder, chital diet is mainly comprised of graminoid species (Schaller 1967; Martin 1982; Johnsingh & Sankar1991). Thus, the higher difference in the abundance of chital in park than the corridor may be due to proportionally less available area of phanta with possibly lower habitat quality in the corridor. Composition of phanta was significantly ($p \leq 0.05$) higher in the park than the corridor. Habitat quality in the corridor may also have been affected by anthropogenic activities although there was low density of livestock pellets in phanta and riverine forest. Moreover, the alien plant species *Lantana camara* had spread widely, probably reducing the habitat quality for ungulates in the corridor, as was also suspected by Karki (2009). Ungulate populations, particulary chital, increased in the park after it was declared a park, which strictly restricted the utilization and extraction of resources by local people (Wegge et al. 2009). In addition, grasses in the phantas and floodplain of the park are cut and burned annually which improves the nutritional quality of the grasses (Moe & Wegge 1997). Chital was found to be evenly distributed across different habitat types in the park, while it was abundant in riverine forest of the corridor. In dry season in the park, chital preferred riverine forest (Moe & Wegge 1994) due to availability of flower and leaves of *M. phillippinensis* and fruits and leaves of *F. racemosa* and *S. cumini* (Dinerstein 1979b). Johnsingh (1981) also found that chital diet comprised of 13-70% of fruits during dry season in Bandipur Tiger Reserve, India. Riverine forest also offer shade and cover during dry season as large areas of grassland are surrounded by riverine forest which can be accessed easily at night (Moe & Wegge 1994). Thus, this may explain the relatively high abundance of chital in riverine forest of the corridor in my study during the cool dry season.

Similarly, hog deer had seven times higher abundance in the park than in the corridor. Hog deer was most abundant in the tallgrass floodplain both in the park and the corridor. The hog deer abundance in the tallgrass floodplain of park is in line with previous studies (Dinerstein 1980, Odden et al. 2005, Wegge & Storaas 2009). The lower abundance of hog deer in the corridor in comparison to the park may be due to relatively greater area ($p \leq 0.05$) of tallgrass floodplain in the park than in the corridor. In addition, livestock grazing appears to be another important factor affecting the abundance of the hog deer in the corridor, since livestock pellets were very abundant in tallgrass floodpain (Table 4). Apart from dominant *S spontaneum* (Dinerstein 1979a), main diet of hog deer (Dhungel & O'Gara 1996), in tallgrass floodplain; other species of graminoid preferred by livestock was found to cover considerable area on the fringes of corridor floodplains. Besides, other human activities like *Zizyphus jujuba* fruit collection and grass cutting were quite high in the tallgrass floodplain. All these factors contributed to low habitat quality of the tallgrass floodplain habitat in the corridor, thereby limiting the distribution of hog deer. It is clear from visual inspection of hog deer and livestock distribution maps in the corridor (Figure 19 & 22) that hog deer prefer areas with minimal livestock activity. Particularly, the hog deer population appeared to be aggregated in the floodplains in the south-east part of the corridor next to Babai river where grazing is restricted.

Contrast to chital and hog deer, wild boar had nearly two times higher abundance in the corridor than in the park. The higher abundance of wild boar in the corridor may be due to the spatial arrangement of habitats. The forest cover in the corridor is greatly fragmented in the middle part by large stretches of agricultural land with settlements i.e. mosaic of forests and agricultural land. This has created habitat edge to agricultural land in a large part of the corridor. According to Dinerstein (1979b), wild boar needs a more nutritious diet (i.e. high quality digestible food per body weight per day) than other larger ruminants, which attracts them to feed on cultivated plants. Breeding throughout year (Dinerstein 1979b), wild boar reproduction depends heavily on the availability of food and, thus, body condition in females (Hutchins et al. 2003). Thus, the greater abundance of the wild boar in the corridor may be due to presence of cultivated plants in the forest edge along its vast length. This interpretation is supported by the distribution pattern of wild boar in the park, which showed that they were common in the Sal forest bordering settlements and cultivated land. Wild boar was ubiquitous across all habitats of the corridor, but Karki (2009) and Adhikari & Khadka (2010) estimated greater mean dungs per plot in the phanta.

Other preferred prey species like swamp deer and nilgai were rare in the park. In the corridor, nilgai was present in very small numbers, whereas swamp deer was absent. Nilgai was the most abundant park ungulate after chital in a 1976 census (Dinerstein 1980). After the declaration of the park, reduced grazing competition between wild and domestic animals caused an increase in vegetation cover (Wegge et al. 2009). Nilgai population may have suffered a decreased in the park due to increased predation by the rising number of tigers as a result of poor visibility in the lower forest strata (Wegge et al. 2009). This is because nilgai depends on visual detection of predators for successful escape (Sheffield et al. 1983). Sambar deer, another preferred tiger prey species (Hayward et al. 2011), was rare in the park and absent in the corridor. Livestock comprises a small portion of tiger diet in the park (Grey 2009). Livestock was absent in the park, but was very abundant in Khata corridor after wild boar. Among different habitat types, livestock dungs were observed more often in degraded scrub followed by tallgrass floodplain in the corridor.

The land use study in the corridor revealed the forest cover of 49.6% in 2011, which seemed to be intact from the cover in 1997 (49.7%). Likewise, there was not any significant change in the coverage of other land types such as tallgrass floodplain, phanta and agricultural land with settlement from 1997 to 2011 (Table 7). Shrestha (2004) also estimated 51.2% forest cover in the corridor in 2001, which is nearer to the conditions in 1997 and 2011. In the corridor, mixed forest occupied most of the area (53.8%) followed by Riverine (17.7%), Sal forest (11.9%), secondary forest (5.9%), phanta (4.1%), tallgrass floodplain (3.6%) and degraded scrub (2.9%). The mixed forests in various locations of the corridor were former riverine and Sal forests as evidenced by their constituent species. Eradication of malaria in terai region after 1954 made flow of people from hilly region for settlement and agriculture (GoN 2007). Thus, these forests may have been degraded much during the period for clearing land for settlement and agriculture, getting material for building construction, and later on for firewood and fodder collection. Over period of time the present state forest may have reached from succession.

CONCLUSION

The abundance of major tiger prey species is relatively low in the corridor compared to the park, with the exception of wild boar. My study suggests that tiger habitat quality was not good in the corridor. The lower abundance of preferred tiger prey in the corridor compared to the park is also of immediate concern. However, the density of wild boar was greater in the corridor and it may thus be a hope that the population of wild boar can fulfill the feeding needs of the tiger. This may somehow help the transboundary dispersal of the tiger between Bardia National Park of Nepal and Katarniaghat Wildlife Sanctuary of India. In case the habitat of tiger is restored with sufficient amount of prey animals in the corridor, the tiger density will probably increase. This will lead to increased tiger human conflict in the form of livestock depredation and human casualty due to small habitat area. Thus, it becomes important to think about solution for this potential problem before the tiger habitat is completely restored in the Khata corridor.

RECOMMENDATION

On the basis of my study, I recommend the following actions in order to increase the abundance of tiger prey in the Khata corridor:

- The parts of the corridor adjoining Geruwa and Orai rivers have been the focus under TAL program and habitat restoration work is concentrated along these. The middle part of the corridor and area adjacent to Babai river which had low prey abundance and greater livestock pressure should also be prioritized.

- As the abundance of chital in the corridor was affected by poor habitat quality of phantas, the forage quality of grasses in the habitat should be improved by cutting and burning annually. Similarly, more active afforestation program should be carried out in degraded areas.

- Alien plant species *Lantana camara* was another factor affecting the habitat quality in corridor. It is spreading badly engulfing both forest and grasslands. An effort should be centered on containing the spread of this species and decreasing the current proliferation in invaded areas.

- Livestock pressure was most important problem influencing the prey abundance in the corridor. So livestock grazing should be restricted in prime tiger prey habitat and particular areas should set aside for it.

- Despite good forest cover, the lower abundance of tiger prey in the middle and north-eastern parts of corridor may be due to the scarcity of water. Only available water source in the north-east side is irrigation canals from Babai river, which is too deep and narrow for wildlife access. So water holes should be constructed in these areas.

- It is necessary to develop linkage between parts of the corridor adjacent to Orai and Babai rivers in the scenario of increased tiger human conflict brought by elevated population of tigers from the restoration of the habitat. It will provide little more habitat area to the increased tiger population which will further facilitate the dispersal to Katarniaghat Wildlife Sanctuary.

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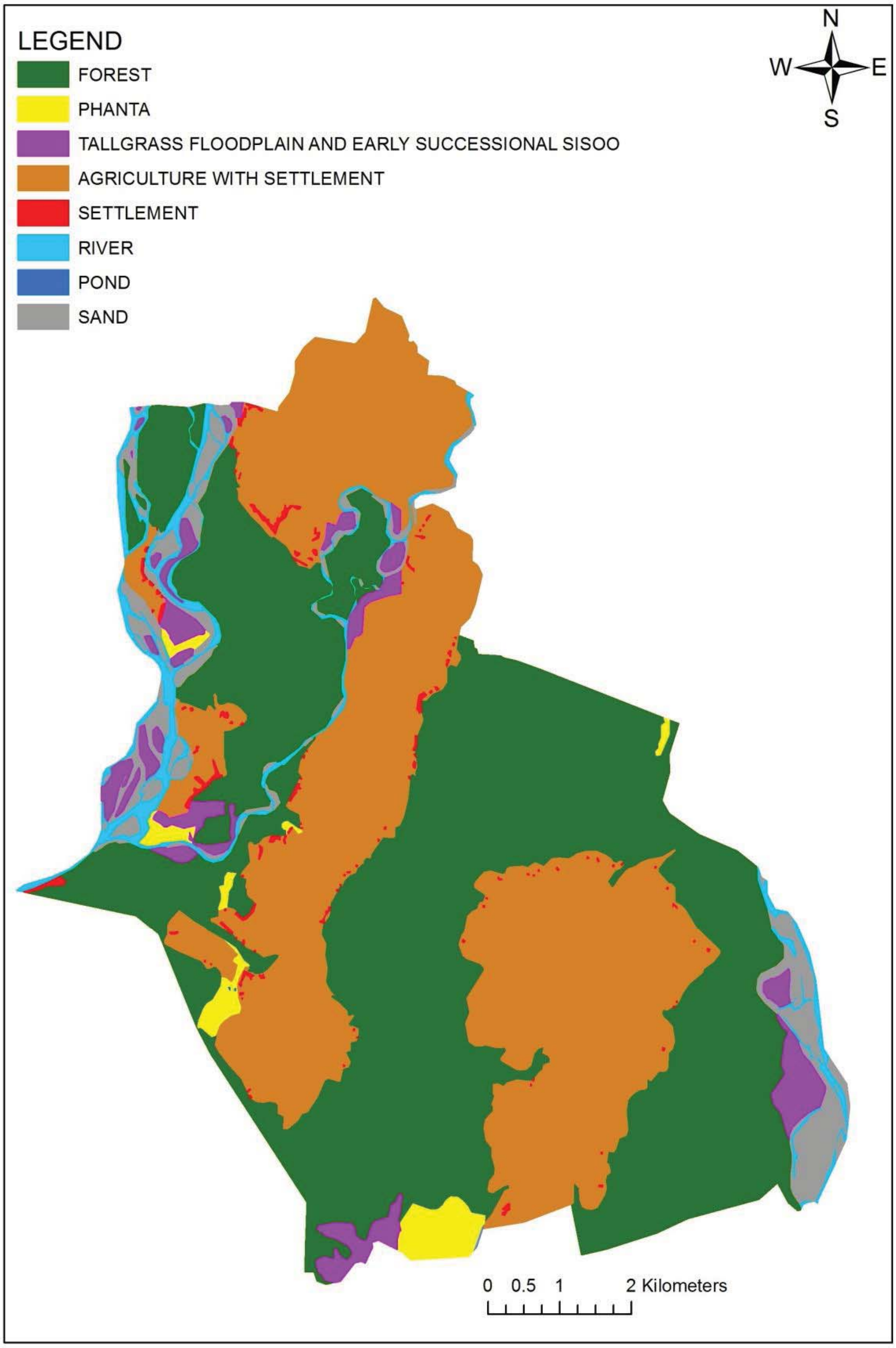
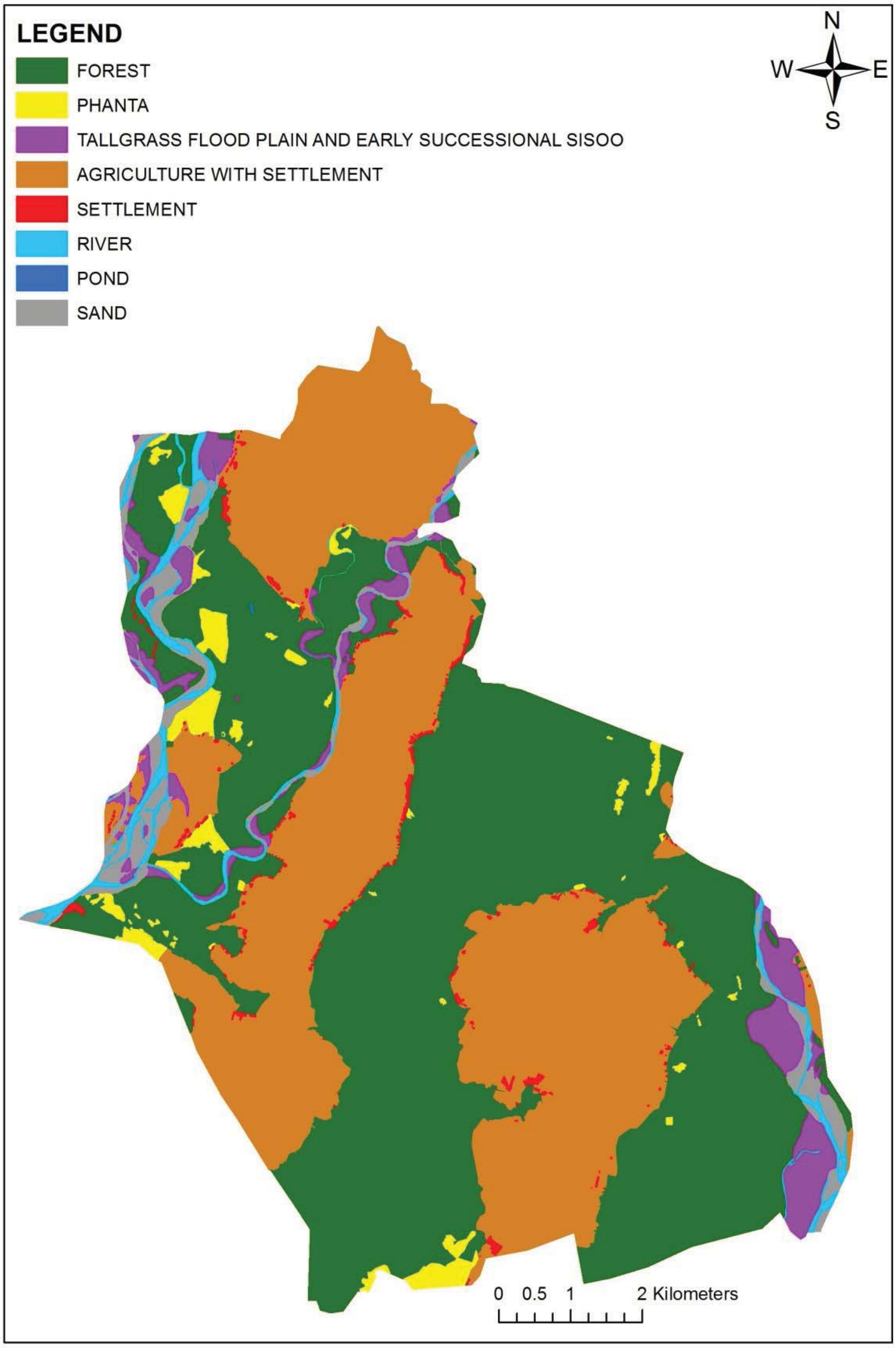
APPENDIX



LAND COVER IN BARDIA-KATARNIAGHAT CORRIDOR IN YEAR 1997



LAND COVER IN BARDIA-KATARNIAGHAT CORRIDOR IN THE YEAR 2011

LIST OF PLATES

Reference pellet groups of tiger prey base available in BCP office

Chital pellet groups in phanta of south-west corner of Bardia National Park

Hog deer pellet groups in tallgrass floodplain of park

Barking deer pelllet groups in Sal forest of park

Barasingha pellet groups in phanta of the park

Sambar deer pellet groups in Sal forest of the

park

Nilgai latrine in phanta of Khata corridor

Goat pellet groups in degraded scrub of the Corridor

Old cattle dung and goat pellets in tallgrass floodplain of the corridor

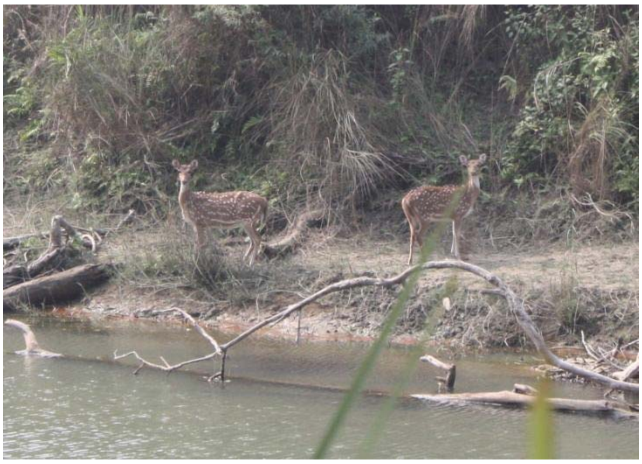
Tiger scat in the island of Geruwa river in the corridor

Wild boar diggings in the corridor

Barking deer pellet groups in mixed forest of the corridor


Wild boar dung in the corridor


Footprint of tiger in the park


Chitals in riverine forest of park


Hog deers in tallgrass floodplain of park


Python in Riverine forest of the park


Female rhino (No. 19) with calf near tallgrass floodplain in the park

Male langur in Sal forest of the park **Termite mound in Sal forest of the park**

Sal forest in the park **Riverine forest in the park**

Phanta in the south-west corner of the park

Old Sissoo plantaion in the north side of the corridor

Tallgrass floodplain inside the park

Water hole in the corridor

Livestock grazing in phanta near Dalla post in the corridor

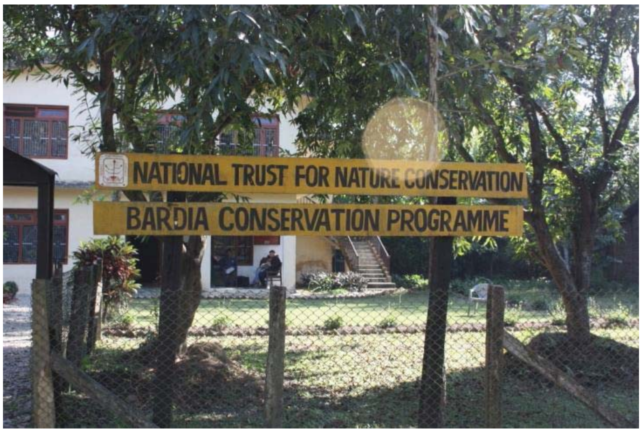
Livestock grazing inside Sal Forest of Dhodhari VDC in the corridor

Livestock grazing in tallgrass floodplain

Traps set up in the way near agricultural field

in the corridor **for catching chital and nilgai near Bandalipur of the corridor**

Infestation of alien plant species *Lantana camara* in the corridor



National Trust for Nature Conservation office in Thakurdwara, Barida

Posing with co-workers (forest guides) of NTNC