Asian Journal of Conservation Biology, July 2017. Vol. 6 No. 1, pp. 38-44 AJCB: FP0082
ISSN 2278-7666 ©*TCRP* 2017

The spatial distribution of ungulates and primates across the vegetation gradient in Bardiya National Park, West Nepal

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(Accepted: July 02, 2017)

ABSTRACT

Bardiya National Park (BNP) in Nepal harbours a significant number of tigers. To ensure the tiger's survival in the future and allow populations to increase in Nepal as aimed by the Tx2 campaign, more ecological knowledge of the region is needed for management of prey. This study gained information on the distribution and density of ungulate and primate prey species and their biomass in BNP across three vegetation types, as changes in prey density will have implications for increasing tiger populations. On average, the total tiger prey population showed a 38.4% decline to a density of 36.47 individuals per km^2 and biomass a 18.7% decline to 2521.21 kg/km^2 compared to 1976, when Bardiya became a protected area. Grasslands supported the highest prey biomass and densities over the seasons, making them a crucial habitat type. Currently, BNP has reached its carrying capacity for the number of tigers it can support. As the limited area of floodplain, riverine and grassland vegetation acts as a bottleneck, we propose to optimize the ecosystem of BNP by active management to allow an increase in habitat productivity and thus in the number of ungulates, and consequently in the number of tigers that feed on them.

Keywords: *Panthera tigris*, prey population, biomass, density, Bardiya National Park, Nepal.

INTRODUCTION

Over the last 40 years, the world's tiger (*Panthera tigris*) population showed a dramatic drop to 3200 free-ranging individuals in 2012 (IUCN 2015; Goodrich *et al.,* 2015). Over de last two generations, the total population has declined more than 20% and none of the existing subpopulations consists of more than 250 mature individuals, leading to the status of 'endangered'(A2bcd + C1 ver. 3.1) on the IUCN Red list (Goodrich *et al.,* 2015). Furthermore, the tiger is mentioned to be threatened with extinction in the Convention on International Trade in Endangered Species of Wild Fauna and Flora to prevent illegal activities (CITES 2013). Historically, the tigers' range stretched across Asia, from the Caspian Sea and Turkey to the island of Bali in Indonesia and the Russian Far East (Nowell & Jackson 1996; Dinerstein *et al.,* 2007). At the present day, tigers have lost over 93% of their historic range (Sanderson *et al.,* 2006; Walston *et al.,* 2010b). Apart from hunting and poaching this decline is mainly due to habitat loss in the form of human settlements and deforestation, as Asia is a densely populated and rapidly developing region, bringing large pressures to bear on the large wild areas required for viable tiger populations.

In 2010, the governments of tiger range countries set the goal of doubling the number of tigers by 2022, the 'Tx2 campaign', following an initiative by the WWF (GTRP, 2010). The government of Nepal announced an increase of 63% in the number of tigers in the country, from 121 in 2009 to 198 individuals in 2013 (GON, 2013; Aryal *et al.,* 2015). However, to ensure the tiger's survival in the future and allow the population to increase further in Nepal as aimed; more ecological knowledge is needed for adequate management of prey densities, next to increasing the connectivity between forest fragments or translocation of animals to ensure viable subpopulations (Odden, 2007).

The Terai Arc landscape in the lowlands of south western Nepal consists of large nationals parks such as Chitwan (CNP), Banke NP (BaNP) and Bardiya (BNP) and holds the core tiger sub-populations in the country (GON, 2013). The abundance of a sufficient prey base of large herbivores is a major factor determining tiger density (Sunquist & Sunquist, 2002). Tigers require an average daily dietary uptake of meat of 5-6 kg a day for adult females and 6-7 kg a day for adult males, resulting in an average meat consumption of 1825–2190 and 2190–2555 kg a year respectively (Sunquist, 1981). Prey species vary from small mammals to the largest of ungulates, with the average weight of prey around 60 kg (Sunquist, 1981). Large herbivores such as deer form the main part of the diet of the tiger and contribute up to 75% of the food uptake (Sunquist & Karanth, 1999). The prime tiger prey base in this landscape is formed by chital *(Axis axis)*, sambar

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(*Cervus unicolor*), hog deer (*Axis porcinus*), wild boar (*Sus scrofa*), barking deer (*Muntiacus muntjak*), swamp deer (*Cervus duvauceli duvauceli*), Hanuman langur (*Semnopithecus entellus*) and rhesus monkey (*Macaca mulatta*) (Dhakal *et al.,* 2014). The ungulates, especially chital and swamp deer often forage in association with the two primate species Hanuman langur and rhesus monkey (Dinerstein, 1979b).

Ungulate populations can be classified into grazers whose diet is dominated by grasses, browsers whose feeding mainly depends on woody plants and mixed feeders who feed on both grasses and more woody plants (Dinerstein, 1979b; Khatri, 1993; Pokharel, 1996). Chital is a common ungulate and is considered a mixed feeder and a habitat generalist, while swamp deer and hog deer are grazers living in the floodplain, muntjac and sambar are browsers and forest-dwelling species (Dinerstein, 1979b; Khatri, 1993; Pokharel, 1996; Wegge *et al.,* 2006). Large herbivores both depend on and influence the structure, composition and biodiversity of the ecosystem by grazing, browsing and the dispersion of fruits, and consequently influence the habitat of other species (Crawley, 1983; Kortlandt, 1984; Owen-Smith, 1987).

Bardiya National Park (BNP) in the Terai Arc landscape of Nepal harbours a significant number of tigers. In 2013, the density of the Bengal tiger (*Panthera tigris tigris*) was estimated at 3.33 individuals per 100 km^2 with the total population estimated at 50 ± 4 individuals in BNP (GON, 2013; Dhakal *et al.,* 2014; Shrestha, 2015). Like other natural areas in Asia, Bardiya National Park also suffered from poaching, human expansion and deforestation. When given the status of a national park in 1988, human settlements were relocated and cattle grazing and cultivation suddenly stopped and burning was restricted, causing changes in the vegetation. Areas that once were grasslands were invaded by trees and bushes (climax vegetation), short grass areas, previously maintained by cattle grazing, changed into long grass vegetation and the undergrowth in sal (*Shorea robusta*) forests became less attractive for grazing ungulates because of massive recruitment of young trees forming impenetrable thickets (Dinerstein, 1979b, 1979c). These changes in vegetation seem to have had a negative impact on several species of large ungulates in the park, as nilgai (*Boselaphus tragocamelus*) still constituting of 10% of all ungulates (and 35% of ungulate biomass) in 1976 is now almost locally extinct, which raises the question about the current status of other prey species (Dinerstein, 1979b).

The aim of this study therefore is to gain information on the current distribution and density of prey species and their biomass in BNP across three main vegetation types, to establish if prey densities and biomass have changed since Bardiya became a protected area. A second aim is to study if habitat use of ungulates and primates varies between seasons. This information is needed to calculate whether the number of tigers in BNP can increase as proposed by the Tx2 campaign, as changes in prey density will have implications for increasing populations (Aryal *et al.,* 2015; van Lunenburg & Kral & van Alphen, 2016).

Study site

The Royal Bardiya National Park is located in the Terai lowlands of south-western Nepal. It was established as the Karnali Wildlife Reserve in 1976 and was long regarded as a popular big game hunting area (Dinerstein, 1979b). In 1988 it was given the status of a national park, resulting in the end of hunting, burning and the relocation of more than 1500 households and livestock (DNPWC 2015). The national park covers a protected area of 968 km^2 and 327 km^2 of buffer zone consisting of human settlements, forest and private land. The park is bordered by the Karnali River in the east and the Churia hills in the north and has an average altitude of approximately 500 meter. The climate is defined by three seasons; the dry winter from October until early April with warm days and cool nights, the hot, dry summer from April until June when temperature can rise up to 45°C and the monsoon season from June until September (DNPWC, 2015). The annual rainfall is 2225 millimetre on average and occurs primarily during the monsoon season (Moe & Wegge, 1997). Bardiya National Park supports more than 230 species of birds and 30 species of mammals, including the Bengal tiger (*Panthera tigris tigris*), Asian elephant (*Elephas maximus*) and one-horned rhinoceros (*Diceros unicornis*) (DNPWC 2015). The park is also home to populations of ungulates that form the tiger's prime prey base (DNPWC 2015). The main vegetation types present in the south western part of the park were described by Dinerstein (1979) and can in 2014 roughly be divided into four habitat types: (1) On the higher soil the fire-resistant *Shorea robusta* and *Buchanania latifolia* forest (also known as sal forest) covers over 70% of the land area (Dinerstein, 1979b; Sharma, 1999; Odden, 2007). (2) Open savannah grasslands on formerly burning sites consisting of the dominant grass *Imperata cylindria* sometimes mixed with wooded patches of *Acacia catechu, Dalbergia sissoo* and *Bombax savannah.* (3) The riverine complex with mixed hardwood forests consisting of *Ficus glomerata, Mallotus philippinensis* and *Eugenia jambolana.* (4) Tall grass flood plain, mainly formed by the taller *Saccharum spontaneum* (Dinerstein, 1979b; Sharma, 1999; Odden, 2007). The latter three vegetation types are found on lower soils, in the flood plain of the rivers.

MATERIAL AND METHODS

Field work was performed in the south-eastern triangle of Bardiya National Park during two seasons: the beginning of the dry winter in November and December 2014 and in the beginning of spring in March 2015. Methods used in November and December 2014 were similar to Dinerstein (1979) and included transect censuring. Data collection took place at either dawn or at dusk every second day. To estimate ungulate population density six transects were established in the three vegetation types, with two transects per vegetation type. Tall grass flood plain habitat was not surveyed because of minimum sight by the thick and tall vegetation and absence of roads and paths. Censuring was done by a 4x4 motor vehicle at a constant speed, with an exception of one transect in savannah grassland. Censuring there was done on foot in

Table 1. Ungulate density (N) per vegetation type in km^2 derived from transects counts during November and December 2014 and primate density (N) per vegetation type in km^2 derived from transects counts during March 2015. Transect counts were conducted for savannah grasslands (N=23), sal forest (N=30) and riverine forest (N=30). Observed ungulates included *Axis axis, Axis porcinus, Cervus duvaucelii, Sus scofra* and *Muntiacus muntjak.* Observed primates included *Semnopithecus entellus* and *Macaca mulatta.*

	Ungulates	**Primates**	**Total**
Vegetation type	**Density in (N/km^2)**	**Density in (N/km^2)**	**Average prey density in BNP (N/km^2)**
Savannah grassland	46.96	88.50	
Sal forest	33.67	5.00	
Riverine forest	3.83	13.80	
Average 2014-2015	26.57	10.90	37.47
Average 1976*	46.45*	14.40*	60.85*

.*From Dinerstein (1979b).

absence of a road and took place every four days to minimize disturbance. All transects had a length of 2.0 kilometer and a width of 200 meter, 100 meter on each side of the vehicle. Transects were determined making use of aerial images from Google Earth (2014). Park roads running through the middle of the grasslands and the size of animals relative to the height of grasses ensured that animals could be seen. When ungulates or primates were observed, the species, total number of individuals, GPS-coordinates, number of males and females were noted, together with date, time and habitat type, making use of a Bushnell rangefinder to ensure that animals were within a perpendicular distance of 100 meter. If primates and ungulates were observed (foraging) together the number, species and distance to the other species was noted. In addition to transect censuring, GPS -coordinates and corresponding vegetation types of ungulates and troops of primates that were observed opportunistically were recorded. All animals were free-ranging and observed under natural conditions. Data were processed in Microsoft Excel and data-analyses were performed in SPSS (version 22). Chi-squares tests and One Way ANOVA's were used to investigate statistical differences in numbers between vegetation types and seasons.

RESULTS

Transect counts and opportunistic observations during November and December showed that chital (*Axis axis*) was the most abundant ungulate in Bardiya National Park in all habitat types, and counted for 87% of the observed ungulate population. Swamp deer formed 10% of the total ungulate population, but were only observed in savannah grasslands or in the adjacent sal forest. Together with chital, they accounted for 97% of the total wild ungulate population. Hog deer (*Axis porcinus*), barking deer (*Muntiacus muntjak*) and wild boar (*Sus scofra*) occurred in lesser numbers. The endangered sambar (*Rusa unicolor*) was only five times opportunistically observed during this research period. During this period 55 groups of primates Hanuman langur (*Semnopithecus entellus*) and rhesus monkey (*Macaca mulatta*) were observed opportunistically, 64% of the groups were Hanuman langurs and 36% of the groups were rhesus monkeys. The average tiger prey density measured during was 37.47 animals per km^2 (Table 1). Per vegetation type the densities are shown in Table 1. The five large ungulate species observed in the transects (*Axis axis, Axis porcinus, Cervus duvaucelii, Sus scofra* and *Muntiacus muntjak*) showed significant differences in total numbers per vegetation type, the largest number and percentage of ungulates were found on the savannah grasslands and sal forest compared to the riverine forest (resp. 46%, 43% and 5%) (χ^2 = 315.13, df = 2, P < 0.05). The large ungulates and primates observed in BNP showed significant differences in distribution across the different seasons (Figure 1). During spring in March, the riverine forest is the most used habitat for tiger prey species. Both ungulates and primates are most abundant in riverine forest during this season, resp. 81% and 87% of the groups is found in this habitat type. This habitat type is significantly more used than savannah (and sal forest) during spring (resp. ungulates: χ^2 = 74.06, df = 1, P < 0.05 and primates: F (2,3) = 12.86, P < 0.05). In March, the primates in the riverine forest and savannah grassland were feeding on young leaves and flowers of the trees and the first figs of the spring season. The primates foraged mostly on flowers and fruits of *Bombax ceiba*, *Syzygium cumini*, *Ficus racemosa*and grass (resp. 35%, 15%, 15% and 14% of foraging events). In more than 29% of these occasions ungulates and primates were observed foraging closely, on an average distance of 21 meter. The ungulates foraged for example on flowers of *Bombax ceiba* that fell down when the monkeys foraged on these trees (pers. obs. Mari van Lunenburg). Also, the primates and ungulates were found foraging ongrass in close proximity (< 5 m) of each other. Overall, during the dry winter tiger prey species were observed more often in sal forest and savannah grasslands than in riverine forest (ungulates: χ^2 = 612.9, df = 2, P < 0.05, primates: χ^2 = 14.813, df = 2, P < 0.01). Moreover, in spring significantly fewer primates were observed in sal forest compared to during winter (χ^2 = 5.538, P < 0.05, resp. N = 3 and N = 22, Fig. 1) and in the riverine forest more monkeys were observed in spring compared to during winter (χ^2 = 22.154, P < 0.01, resp. N = 45 and N = 16, Figure 1).

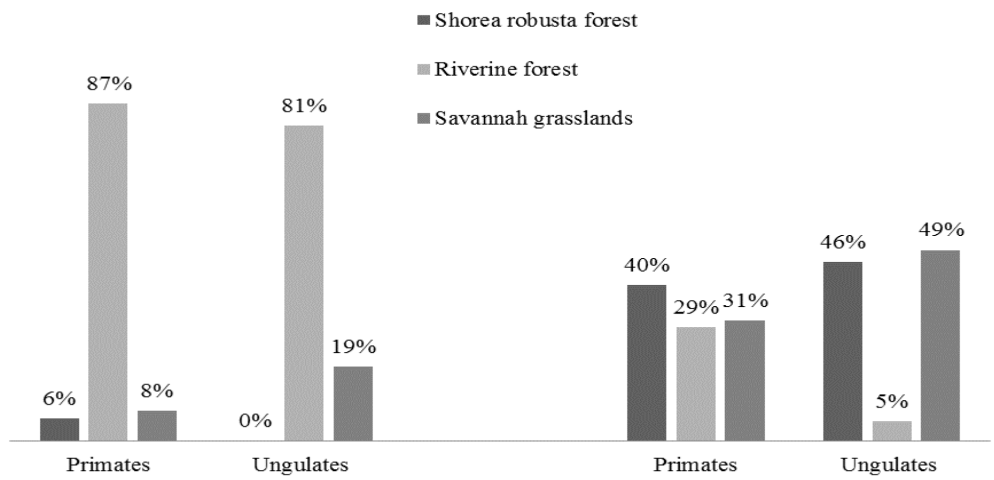

Figure 1. Distribution of prey species in percentage of groups per vegetation type per season; spring and winter. Primate and ungulate vegetation type use between different seasons differs significantly (resp. χ^2=39.462, p < 0.05 and χ^2=74.06, df=1, p<0.05).

Table 2. Average ungulate biomass from transect counts for savannah grasslands (N=23), sal forest (N=30) and riverine forest (N=30) in kg/km^2 and percentage of total ungulate biomass per vegetation type (%). Observed ungulates included *Axis axis, Axis porcinus, Cervus duvaucelii, Sus scofra* and *Muntiacus muntjak.* Observed primates included *Semnopithecus entellus and Macaca mulatta.*

	Ungulates		**Primates**			**Total**
Vegetation type	**Average biomass* per vegetation type (kg / km^2)**	**Percentage of total biomass* per vegetation type (%)**	**Average ungulate biomass* vegetation type (kg / km^2)**	**Percentage of total biomass* per vegetation type (%)**	**Percentage of ungulate biomass* per vegetation type (%)**	**Average prey biomass BNP (kg/km2)**
Savannah grassland	5087.33	69.78	647.95	4.78	0.14	
Sal forest	1989.10	27.28	36.81	8.32	0.24	
Riverine forest	213.75	2.93	101.05	86.90	4.43	
Average 2014-2015	2430.06		91.46			2521.52
Average 1976*	2981*		120*			3101*

* Biomass per species and sex were taken from Dinerstein (1979b).

In terms of biomass, chital was the most common ungulate and contributed 76% to the ungulate biomass. While swamp deer formed only 10% of the total ungulate population, it formed almost a quarter (22%) of the total wild ungulate biomass. The contribution of hog deer, barking deer and wild boar to the total biomass is negligible (Figure 2). The average total tiger prey biomass found over the year 2014-2015 was 2521.52 kg/km^2 (Table 2). The transect data per vegetation type from November and December showed that the grasslands supported a factor 2.56 more ungulate biomass per km^2 than the sal forest on average. In March the primates showed the highest biomass/km^2 on savannah grassland, the highest total numbers of groups and individuals were observed in riverine forest. The grassland supported a factor of 14.89 more total primate biomass per km^2 than the riverine forest on average (Table 2).

DISCUSSION

The current density of prey species and their biomass in BNP has considerably changed compared to 1976 when Bardiya became a protected area. In terms of density, ungulates declined 43.8% compared to 1976 and primates showed a decline of 24.3%. On average, the total tiger prey population showed a decline of 38.4% to a prey density of 36.47 individuals per km^2 since 1976. In 1976, nilgai (*Boselaphus tragocamelus*) represented 34% of the total wild ungulate population (Dinerstein, 1979b). At the present moment nilgai is near extinction in BNP, resulting in a decline of the tiger prey population, as described by Odden (2007). Hog deer and barking deer, both habitat specialists, also showed a decline in numbers compared to 1976 (Dinerstein, 1979b). When Bardiya became a national park and the intensive grazing, cutting

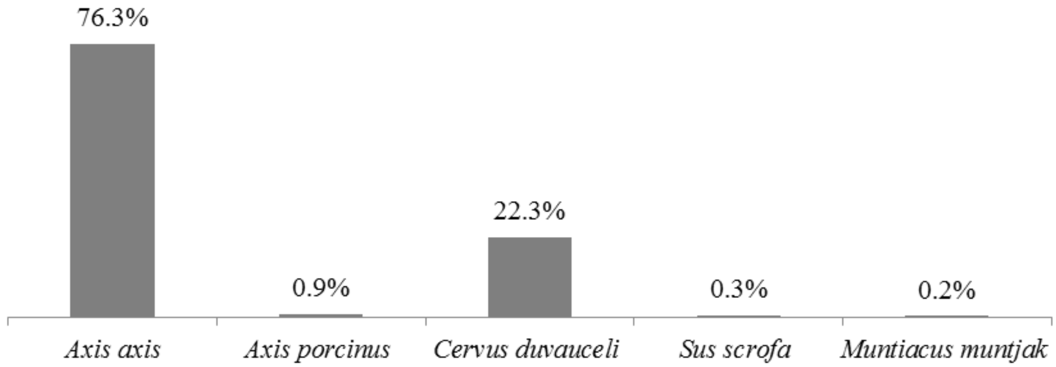

Figure 2. Contribution to the total wild ungulate biomass in percentage species. Observed species included *Axis axis* (N=1652, ♂=382 and ♀=1270), *Axis porcinus* (N=26, ♂=9 and ♀=17), *Cervus duvauceli* (N=178, ♂=100 and ♀=78), *Sus scrofa* (N=7, ♂=2 and ♀=5) and *Muntiacus muntjak* (N=12, ♂=3 and ♀=9). Data include both transect and opportunistic counts and collection took place for 37 days during November and December 2014. (* Biomass per species and sex were taken from Dinerstein (1979).

and burning stopped, the vegetation grew towards climax vegetation with tall grasses that are not palatable. In general, the forest became much denser, with often a closed canopy, resulting in decreased grazing opportunity in the forest. Tall grassland increased at the expense of short grassland, which became scarce. As tall grassland contains the lowest density of ungulates and is not suitable for grazing during most of the year, this has resulted in a decrease of suitable habitat for grazers and habitat specialists (Dinerstein, 1979b). Although the number of chital, a habitat generalist, have increased after Bardiya became a national park, several specialist species of Terai ungulates other than nilgai have gone extinct. Gaur (*Bos gaurus*), which had already disappeared when Bardiya became a national park, black buck (*Antilope cervicapra*) - a species that needs short to middle high grassland- and pygmy hog (*Porcula salvania*) – also a grazer- have gone extinct in Nepal (although a captive population of local blackbucks could be used to introduce the species back into the wild when suitable habitat becomes available) (Mallon, 2008; Narayan *et al.,* 2008). In terms of biomass, ungulates showed a decline of 19.5% and primate biomass decreased with 23.8%. On average the total tiger prey population showed a decline in biomass of 18.7% compared to 1976. Savannah grasslands supported the highest tiger prey biomass and number of individuals during both seasons, making them a crucial habitat type for tiger prey species survival.

A significant difference in habitat use was observed over the seasons. During the cold dry winter, tiger prey species concentrate in the sal forest and savannah grasslands while in the spring (*i.e.* the warm dry season) highest densities were observed in riverine forest. The major part of BNP consists of forest on higher soils (J.J.M. Alphen personal communication), because human settlements around BNP have preferentially chosen the lower soils in the flood plain for agriculture as these soils can easily be irrigated in the dry season and allow the cultivation of rice in the wet season, As a result, ungulates and primates leave the forest after the cold dry season around March because of drought, and absence of food for species that are otherwise common in the sal forest and move to the savannah grasslands and riverine forests with the adjacent flood plain. Here shoots, leafs, fresh grass and the first fruits are emerging in this time of the year because rising temperatures and the availability of water already allow fresh vegetation to sprout. Similar observations were made by Dinerstein (1979) and Wegge (2009). Habitat productivity therefore can strongly influence ungulate and primate densities. However, the riverine and floodplain vegetation is limited to a narrow area in BNP, bordering the Babai River and to the inland delta of the Karnali River, which may limit the numbers of ungulates. A large section of the flood plain lies outside the park and is buffer zone under cultivation. The surface area of floodplain, riverine and grassland vegetation serves as a bottleneck and is thus a limiting factor for the abundance of prey species and therefore for the number of tigers BNP can support.

The decrease in tiger prey density and tiger prey biomass from 1976 to 2014-2015 has resulted in a decrease of the carrying capacity for tigers in BNP from 55 to 45 (van Lunenburg *et al.,* 2016). Hence, with its current population of estimated ±50 tigers BNP has reached its carrying capacity and therefore in its current state cannot support an increase in the number of tigers as targeted by the Tx2 campaign. On the basis of our data, we propose to optimize the ecosystem of BNP in a way that habitat productivity and consequently the population of ungulates increases by creating more open and diverse forests and more short grassland by human intervention. Possible management actions could include further protection of the flood plain and riverine forest, avoiding the forest to become denser and prevent the further decrease of productive short grasslands. When management has resulted in these habitats changes, nilgai could be reintroduced and population numbers of mega herbivores such as gaur, elephants and rhino should be increased, if needed by introducing more animals from other places. When mega-herbivores have reached sufficient densities, they can maintain vegetation types suitable for the grazing of ungulates (van Lunenburg *et al.,* 2016). Increasing these areas and thus increasing the diversity of the vegetation is likely to favour population numbers of prey species in Bardiya National Park and allowing an increase in number of tigers that feed on them.

ACKNOWLEDGEMENTS

This paper could not have been written without the support of the Himalayan Tiger Foundation, and that of the staff of Tiger Tops' Karnali Lodge. In particular, we thank Ram Din Mahato, Ashik Gurung and Bhim Thanet for sharing their knowledge of the Bardiya ecosystem. M. van Lunenburg received a grant from KNAW Academy Ecology Fund for ecological research under grant number UPS/375/Eco/J1520.

Disclosure statement

No potential conflict of interest was reported by the authors.

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