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ORIGINAL PAPER

Opportunistic use of camera traps to assess habitat-specific mammal and bird diversity in northcentral Namibia

Andrew B. Stein · Todd K. Fuller · Laurie L. Marker

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Abstract In northcentral Namibia, Waterberg Plateau Park (WPP) is a protected area that acts as a refuge for rare and endangered species, while the farmlands surrounding the Park are managed for livestock production, but support populations of wildlife for game farming, trophy hunting, and conservation. During June–October 2006, camera-traps were set within and surrounding WPP to assess leopard (*Panthera pardus*) density (n = 19 camera stations and 946 camera-trap-nights). Fortuitously, photographic results (2,265 photos of identifiable mammal (n = 37) and bird (n = 25) species) allowed us to assess aspects of species diversity and differences among the Park, the farmland areas along the Waterberg Plateau escarpment, and the flatlands surrounding the escarpment. Species composition among the three areas was markedly different, and made sense with respect to differences in habitat and management features. Camera-trapping efforts, although intended for a narrow purpose, may also provide a rather robust record of differences in mammal and bird diversity in adjacent habitats and can be incorporated into long-term monitoring programs.

Keywords Camera trapping · Farmland · Namibia · Relative abundance · Wildlife survey

Introduction

In recent years, non-invasive techniques such as camera-trapping have been used to determine not only presence–absence, but also the relative abundance of specific species (e.g., Jackson et al. 2006; Trolle et al. 2007b) and of species assemblages (e.g., Carbone et al. 2001; Trolle 2003; Trolle et al. 2007a; Azlan and Sharma 2006), sometimes in a variety of environments (e.g., Moruzzi et al. 2002; Hilty et al. 2006; Kaufman et al. 2007). The

A. B. Stein · T. K. Fuller (✉)
Department of Natural Resources Conservation, University of Massachusetts,
160 Holdsworth Way, Amherst, MA 01003, USA
e-mail: tkfuller@nrc.umass.edu

L. L. Marker
Cheetah Conservation Fund, PO Box 1755, Otjiwarongo, Namibia

information resulting from such surveys is important for understanding and monitoring trends within the local wildlife populations in differing habitats (Martins et al. 2007). The information gathered by such surveys could affect local conservation decisions and assist managers in assessing future policy for particular species or species groups.

In northcentral Namibia, some population surveys occur yearly as part of the standard management practices within and surrounding the Waterberg Plateau Park (WPP), a government protected area. Within WPP, annual 48-h waterhole counts are conducted primarily to monitor a group of protected large mammal species (B. Erckie, pers. comm.). In addition, annual road transect counts are conducted on some adjacent farmlands and, within the Waterberg Conservancy (a group of farms with agreed-upon wildlife conservation practices), 24-h waterhole counts also are conducted during the height of the dry season (Cheetah Conservation Fund 2005). Although these surveys have been conducted concurrently for nearly a decade, non-standardized data collection and analyses make it difficult to compare the results between the two areas. Furthermore, their intended purpose is limited to a relatively small number of species.

We used camera-trapping as a means to count leopards in the area (cf. Karanth 1998). The number and variety of photos obtained during the survey, however, allowed us to inventory mammal, and to a limited extent bird, biodiversity and to compare species composition and relative abundance within the WPP and the surrounding farmlands. Because of current management practices, occurrences of some species (e.g., large herbivores and livestock) are known to differ, but the extent to which occurrence and relative abundance of other species differs is not well known. Since both the physical attributes (e.g., soil and vegetation) and the management of the adjacent areas are so different, an assessment of the usefulness of camera-trapping results to compare habitat biodiversity seemed appropriate. If reasonable differences were identified, the utility of the method for longer-term monitoring could be confirmed.

Materials and methods

Study areas

Waterberg Plateau Park (WPP)

The WPP, located in northcentral Namibia (S 20.46133, E 17.20812), is a 470-km^2 protected area established in the 1970s for the protection of eland (all scientific names of species identified by photo in this study are listed in Tables 2 and 3; otherwise, they are identified in the text) and later as an endangered species park (Schneider 1998). The endangered large herbivores introduced to and currently managed within the Park boundaries include black rhino, white rhino, Cape buffalo, giraffe, roan antelope, tsessebe (*Damaliscus lunatus*), and sable antelope. The plateau is characterized by 200-m high sandstone cliffs with deep sands on top. Average annual rainfall is between 400 and 500 mm (Mendelsohn et al. 2002), with most ground water seeping into underground springs that feed groundwater wells on the farms along the base of the escarpment. To the northeast, the plateau levels off with surrounding farmland. The 479 species of plants can be divided into four different vegetation zones on top of the plateau: fountain plant communities, rocky outcrop communities, bush savanna, and mixed tree and shrub woodland (Jankowitz 1983; Schneider 1998). The fountain plant communities are associated with fig trees (*Ficus sycomorus*) and found along the slopes of the plateau. Rocky outcrop communities are characterized by

Peltophorum africanum growing among the rocks and *Combretum apiculatum* and *C. collinum* growing throughout this vegetation zone. The bush savanna vegetation is dominated by *Terminalia sericea*; *Burkea africana*, *Combretum collinum*, and *Ochna pulchra* also grow in the bush savanna zones. The mixed tree and shrub savanna is characterized by two vegetation types: the open, broad-leaved tree savanna with *Burkea africana* and *Lonchocarpus nelsii*, and sandy regions dominated by *Burkea africana*. These environments contrast with much of the farmlands surrounding the base of the escarpment.

Farmlands

The farmlands surrounding the Park are mostly managed for livestock production and also support populations of wildlife for game farming, trophy hunting, and conservation. Those surrounding the southwestern portion of the WPP are characterized by flatlands with mixed soil types. While the areas at the base of the WPP escarpment are characterized by deep sand, the soils >1 km from the base are mixed clay and black cotton (Schneider 1998). The area is dominated by *Acacia mellifera* and *Dichrostachys cinerea* bush, characterized as the thornveld biome (Barnard 1998; Schneider 1998). The commercial farmlands north and southwest of the WPP are cooperatively managed through the Waterberg Conservancy and support densities of livestock (4.0 individuals/100 km^2) that are nearly half the report density of game (8.8/100 km^2) in the region (Stein 2008). Ground water is pumped to the surface for livestock, but provides water year round for game, as well.

Lions (*Panthera leo*), spotted hyenas, and African wild dogs (*Lycaon pictus*) once occurred throughout the region but were essentially eliminated by 1980s (Schneider-Waterberg, A. Baggot-Smith pers. comm.). Perhaps 38–43 medium and large ($\geq$1 kg, but including two mongoose species <1 kg) mammal species (Kingdon 1997; Hanssen and Stander 2004; Mills and Hes 1997; Skinner and Chimimba 2005) and a variety of bird species (Maclean 1993; Sinclair et al. 1995) potentially occur in the study areas.

Methods

Based on recent sign, we positioned 19 motion-sensor camera stations (Deercam, Non-typical Inc. Park Falls, WI, USA,) along commonly used pathways, riverbeds, and roads within and surrounding the WPP to target leopards between June and October 2006. The first 14 stations were deployed on the farmlands and the southern portion of the WPP for 7 weeks from June to late July. The last five stations were placed within the northern portion of the WPP for 7 weeks between August and October. Each station consisted of two motion-sensor cameras secured to trees at a height of 60 cm, pointing towards the path, but offset from each other at >0.5 m. In cases where sensors were disturbed by excessive motion from vegetation, the cameras were subsequently reset up to 1 m high angled down towards the middle of the cleared path. Eleven stations were placed within the WPP. Eight others were placed in the farmland: four along the Waterberg Escarpment (<1 km) and four within the flat Acacia shrubland (>1 km).

Because the stations were put in place as part of a leopard population survey (Stein 2008), they were spaced according to the minimum home range size as assessed by radio- and GPS-tracking of adult female leopards with cubs (cf. Karanth 1998). The minimum distance between nearest stations was 3.0 km and the maximum distance was 7.8 km. Each station had a scent lure (Tom Miranda's High Plains Predator Call, South Dakota, USA and Russ Carman Dakota Gold Predator Lure, South Dakota, USA) placed on a small rock or stick between the cameras to attract leopards to the stations.

Stations were checked every 2–3 days and the film, batteries, and scent lures were replaced when necessary. Films were developed and scanned to identify species. First, species numbers were recorded according to the total number of photos taken, regardless of time and location. Subsequently, the numbers of photographic "events" were calculated; that is, the number of instances in which the same species was photographed by either of two cameras at a station, within a maximum of 30 min, and also a maximum of 24 h, since the previous photograph of the species. The 24-h period was defined as either from midnight 0000 h to midnight (2400 h) for diurnal species or noon (1200 h) to the following noon (1200 h). We assumed that multiple photographs of the same species were the same individual or the same group as earlier photographed, with the exception of leopards, white rhinos, and black rhinos, which could often be identified individually.

Differences in photographic rates (number of photos/100 camera nights; $\geq$24 h since a previous photo of the same species at the same camera station, with exceptions noted above) for individual species in the WPP and the different farmland areas were tested using a χ^2 goodness of fit test (2 d.f.). Because of the number of tests conducted ($n = 39$), a Bonferroni correction was used to identify statistical significances (i.e., $\alpha < 0.001$).

Results

In total, 4,281 photographs were taken over the entire study area in 946 camera-trap nights, or 452.5 photographs per 100 camera-trap nights. Of these photographs, about half (45.6%; 1,922) were miss-fires or of unidentifiable animals, and 2.2% (94) were of people. Photos also were taken of 37 mammal species, including 6 introduced ungulates, 2 livestock species (cattle and donkeys), 8 other ungulates, 15 carnivores, and 5 other species, as well as a number of unidentifiable small rodents. This number of species included most (88%) of the medium to large mammalian species most likely to be in the area, but not the yellow mongoose (*Cynictis penicillata*), springbok (*Antidorcas marsupialis*), klipspringer (*Oreotragus oreotragus*), rock hyrax or dassie (*Procavia capensis*), and pangolin (*Manis temminckii*), all of which have been seen opportunistically on the surveyed farms. In addition, several photos of a spotted hyena, which were thought to be extirpated from the area, were obtained. Across the entire study area, 25 bird species were identified, as well.

By comparing photos of species taken at the same site, the original 2,359 photos of mammals and birds were reduced to a sample of 1,029 photos of individual species taken at a location within a 24-h period (but including individually identifiable leopards and rhinos; see Methods). From these pictures, we compared the photo rates among the three areas (i.e., Flatlands, Escarpment, and WPP).

Mammal species were not equally distributed throughout the three study areas (Table 1). Introduced ungulates were primarily located within the WPP, as part of the endangered species breeding and reintroduction program. However, the sample sizes were low and the giraffe was the only species photographed statistically more often within the WPP (Table 2). Although livestock were only present on the farmlands, the presence of these species was not statistically different across the study area. Of the remaining ungulates, kudu, oryx, and Damara dik dik were more common along the escarpment, while warthogs were more common on the flatlands. Among carnivores, the African wildcat and slender mongoose were more common on the farmlands, in general, while leopards and bat-eared foxed were more common on the flatlands, and brown hyenas were more common along the escarpment. Scrub hares were more common on farmlands, while springhares and porcupines were more common on the flatlands. Although steenbok, red hartebeest, sable

Table 1 The number (*N*) and percentage of species present (*P*) and significantly more prevalent (+) in adjacent areas of northcentral Namibia, as determined from camera-trapping

Groups	*N*	Farmlands[a]		WPP	
		P	+	*P*	+
Introduced ungulates	6	17	0	100	34
Livestock	2	100	0	0	0
Other ungulates	8	75	50	88	0
Carnivores	15	93	33	87	0
Other mammals	6	100	50	67	0
Birds	25	84	28	44	0

[a] Includes flatlands and escarpment areas

antelope, and aardwolf were photographed only in the WPP, and cheetahs, spotted hyenas, springhares, and small mammals were photographed only in the farmlands or escarpment, sample sizes for these species were too small to detect statistical differences. We note, however, that observations of all of these species were recorded on both farmlands and the WPP within the previous year, with the exception of sable antelope, which are only seen within the Park, and spotted hyenas, which are only known from the photographs.

Bird species diversity was highly variable across the study areas, as well (Table 3). On the farmlands, 10 species were photographed in the flatlands, while 19 species were identified along the escarpment; within the WPP, 12 species were identified. Only six species occurred in all three study areas, whereas eight species were identified only on the farmlands and four species were identified only within the WPP. Helmeted guineafowl, red-billed spurfowl, red-crested korhaan were significantly more common on the farmlands than within the WPP. The cape turtle dove, white-browed sparrow-weaver, crimson-breasted shrike, and grey go-away bird were more common along the escarpment. Although the coqui francolin, African red-eye bulbul, crested francolin, and short-toed rock thrush were only identified within the WPP, the sample size was too small to detect a statistical difference. One Monteiro's hornbill, a national endemic (Jarvis and Robertson 1999), was photographed along the escarpment. More unidentifiable birds, which were small, sometimes in flight and often cast in shadow, were photographed along the escarpment.

Discussion

Although the WPP is adjacent to farmlands, photo-trapping did identify some marked, but not unexpected, disparity in species occurrence and relative abundance among areas, likely due to differences in (1) land and animal management practices, and (2) natural habitats. The Park is an endangered species protected area with a very different array of introduced large herbivores (Schneider 1998), though it also has experienced high harvests of kudu and oryx in the recent past (C. Brown, pers. commun.). Conversely, the farmlands are managed for livestock production and provide grazing for cattle, and to a lesser extent donkeys. Also, the WPP is characterized by deep sand and broad-leafed woody species, grass species of poor grazing value, and little surface water, whereas the farmland and escarpment areas provide very different and higher quality grassland and bush habitats with a variety of water holes.

Photo-trapping also produced some unexpected results. Spotted hyenas had previously been considered as locally extirpated and all regional farmers were unaware of their

Table 2 Photographic rates (photos/100 camera-trap nights; ≥24 h since a previous photo of the same species at the same camera station, except for leopards, white rhinos, and black rhinos which were often individually identifiable) for individual mammal species in and near Waterberg Plateau Park, northcentral Namibia

Species	Flatlands (n = 200)	Escarpment (n = 201)	WPP (n = 545)	*P* value
Introduced ungulates				
White Rhino *Ceratotherium simum*	0	0	2.9	0.0025
Black Rhino *Diceros bicornis*	0	0	3.3	0.0012*
Giraffe *Giraffa camelopardalis*	0	0.5	5.0	0.0001*
Cape Buffalo *Syncerus caffer*	0	0	1.8	0.0242
Sable antelope *Hippotragus niger*	0	0	0.4	0.4795
Roan antelope *Hippotragus equinus*	0	0	1.8	0.0242
Livestock				
Cattle	2.5	1.5	0	0.0023
Donkey	1.0	0	0	0.0245
Other ungulates				
Greater kudu *Tragelaphus strepsiceros*	8.5	15.0	2.2	0.0001*
Southern oryx *Oryx gazella*	5.0	9.5	1.7	0.0001*
Common duiker *Sylvicapra grimmia*	2.5	0.5	1.1	0.1782
Damara dik dik *Madoqua kirkii*	1.0	19.5	0	0.0001*
Eland *Taurotragus oryx*	2.5	0	5.1	0.0022
Red hartebeest *Alcelaphus buselaphus*	0	0	0.4	0.4795
Warthog *Phacochoerus aethiopicus*	12.4	6.0	1.1	0.0001*
Steenbok *Raphicerus campestris*	0	0	0.2	0.6942
Carnivores				
Leopard *Panthera pardus*	9.5	3.0	2.2	0.0001*
Brown hyena *Hyaena brunnea*	4.0	8.0	2.0	0.0006*
Spotted hyena *Crocuta crocuta*	0	1.0	0	0.0238
Caracal *Felis caracal*	1.5	1.0	1.7	0.8106
African wildcat *Felis lybica*	10.0	11.5	1.3	0.0001*
Genet *Genetta genetta*	9.5	6.0	6.	0.2322
Cheetah *Acinonyx jubatus*	0.5	0	0	0.1565
Honey badger *Mellivora capensis*	1.0	1.0	1.3	0.9185
Black-backed jackal *Canis mesomelas*	4.0	3.0	0.9	0.0161
Slender mongoose *Herpestes sanguinea*	13.9	10.5	0.9	0.0001*
Banded mongoose *Mungos mungo*	1.5	0.5	0.6	0.3734
Aardwolf *Proteles cristatus*	0	0	0.7	0.2276
Cape fox *Vulpes chama*	1.0	0	0.4	0.2938
Bat-eared fox *Otocyon megalotis*	2.5	0	0.2	0.0009*
Striped polecat *Ictnonyx striatus*	1.0	0.5	0.9	0.8311
Other mammals				
Chacma Baboon *Papio cynocepalus*	10.4	7.0	5.1	0.0349
Scrub Hare *Lepus saxatilis*	13.4	14.0	2.4	0.0001*
Aardvark *Orycteropus afer*	2.0	0.5	1.1	0.3716
Springhare *Pedetes capensis*	3.0	0	0	0.0001*
Porcupine *Hystrix africaeaustralis*	13.9	5.5	5.1	0.0001*
Unidentified small rodents	0.5	0	0	0.1565

Number of trap nights per study area type in parentheses

* Significant differences (<0.001) among areas

presence. It is unclear how long spotted hyenas have been present, although from our five photographs two individuals were identified in two different stations within a 3-day period. Photographs of spotted hyenas were not acquired after the first week of the camera-trapping effort and therefore these individuals may only have been transients.

Table 3 Photographic rates (photos/100 camera-trap nights; ≥24 h since a previous photo of the same species at the same camera station) of bird species in and near Waterberg Plateau Park, northcentral Namibia

Species	Flatlands	Escarpment	WPP	*P* value
Helmeted guineafowl *Numida meleagris*	32.8	30.5	1.3	0.0001*
Red-billed spurfowl *Pternistis adspersus*	10.0	9.5	0.4	0.0001*
Red-crested korhaan *Lophotis ruficrista*	6.0	8.5	1.3	0.0001*
Kori bustard *Ardeotis kori*	0.5	0.5	0	0.2567
Northern black korhaan *Afrotis afraoides*	0	0.5	0	0.1549
Red-billed hornbill *Tockus erythrorhynchus*	0	0.5	0	0.6408
Southern yellow-billed hornbill *Tockus leucomelas*	2.0	0.5	0.2	0.0215
Monteiro's hornbill *Tockus monteiri*	0	0.5	0	0.1549
Cape turtle dove *Streptopelia capicola*	0.5	3.5	0.4	0.0007*
Laughing dove *Streptopelia senegalensis*	0	0.5	0	0.1549
Crimson-breasted shrike *Laniarius atrococcineus*	0	4.0	0	0.0001*
White-browed sparrow-weaver *Plocepasser mahali*	0.5	2.5	0	0.0007*
Grey go-away bird *Corythaixoides concolor*	0	3.5	0	0.0001*
Double-banded sandgrouse *Pterocles bicinctus*	0	0.5	0	0.1549
Buffy pipit *Anthus vaalensis*	0	1.0	0	0.0238
Spotted thick-knee *Burhinus capensis*	0	0.5	0.2	0.5379
Spotted eagle-owl *Bubo africanus*	0.5	0	0	0.1565
Common quail *Coturnix coturnix*	0	0.5	0	0.1549
Cape glossy starling *Lamprotornis nitens*	0.5	0	0.2	0.5434
Burchell's starling *Lamprotornis australis*	0	0.5	0	0.1549
Coqui francolin *Peliperdix coqui*	0	0	0.2	0.6907
Fork-tailed Drongo *Dicrurus adsimilis*	0	0.5	0	0.1549
African red-eyed Bulbul *Pycnonotus nigricans*	0	0	0.2	0.6907
Crested Francolin *Dendroperdix sephaena*	0	0	0.2	0.6907
Short-toed rock thrush *Monticola brevipes*	0	0	0.2	0.6907
Unidentifiable spp.	2.0	6.5	0.6	0.0001

* Significant differences (<0.001) among areas

Although we located camera stations throughout several different areas, they were specifically set up to take photos of leopards. We recognize that in doing so, some mammal species, and likely many bird species, were not drawn to or even avoided locations where we had cameras. All sites, however, were selected with the same criteria in mind, and therefore should have the same biases across study areas. Thus, even considering the study design, the results provide insights into the study area that are useful beyond the population survey of leopards alone.

Camera studies focusing on a single species almost always will record a variety of other species. The degree to which such results are generally useful in identifying mammal and bird diversity between or among habitats likely varies with the overall abundance of photos, as well as many other factors such as camera placement and lure type. Suggestions for enhancing the opportunities to use cameras in biodiversity studies are as follows. First, placing only one camera per station instead of two would eliminate some double photos and increase total photo opportunities; more camera-nights in more independent locations would increase the capacity to detect differences in species' relative abundance. Second, placing of cameras on well-used trails, as we did, seemed to work well for a variety of mammal species, but perhaps would not work as well for all mammal species in other environments (e.g., tropical forests) or for many bird species; other placement configurations might be biased, as well, but be useful for target species or taxa. Third, our lures seemed to work well for carnivores and did not repel non-carnivores; they may have had some attractiveness to some bird species, but certainly not most. Other attractants for other species, even used in tandem with primary lures, might increase visits of more species. Finally, most diurnal bird species are likely best surveyed by well-established techniques, but identification of more cryptic and nocturnal species might be as efficiently conducted using cameras, and camera results on diurnal species can be used as an independent evaluation method in assessing their relative abundance.

We recognize that designing studies for one purpose and then using results for another can be risky, but in this case, any biases we introduced were consistent among study sites, and therefore support the notion that our comparisons are worthwhile. We certainly encourage others to make the most of their accumulated data, especially if sample sizes are adequate. Even if primarily intended for a narrow purpose, camera-trapping may secondarily provide an important record of differences in mammal and bird diversity in adjacent habitats and can be incorporated into long-term monitoring programs.

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