An inventory of vertebrate roadkill in the Greater Mapungubwe Transfrontier Conservation Area, South Africa

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Using a standard protocol, we conducted vertebrate roadkill surveys in the Greater Mapungubwe Transfrontier Conservation Area (GMTFCA), South Africa, which is a World Heritage Site. A total of 991 roadkill were recorded on the paved roads and 36 roadkill on the unpaved roads. Identifiable roadkill comprised 162 species from 24 orders and 65 families. Ninety-three roadkill could not be identified to species level. Roadkill counts were strongly influenced by road type and season. More roadkill was recorded on the paved than the unpaved roads. Irrespective of road type, the proportion of roadkill was greatest in the hot/wet season (4.3 paved roadkill/km/day paved and 1.3 roadkill/km/day unpaved) and lowest in the cold/dry season (2.0 roadkill/km/day paved and 0.1 roadkill/km/day unpaved). The high numbers of vertebrates identified as roadkill suggests that road traffic has the potential to directly and negatively affect biodiversity conservation in this part of South Africa. We recommend continued roadkill data collection across South Africa to assist with creating an inventory of species most likely to be at risk from roads. This will, in turn, better inform the implementation of potential mitigation measures.

Key words: roadkill, protocol, vertebrates, ecological season.

INTRODUCTION

Growing concern about the ecological effects of roads has led to the emergence of road ecology as a scientific discipline (Forman, 2003; Fahrig & Rytwinski, 2009). Roads impact ecosystems in two ways; indirect impacts through fragmentation of habitat (Hels & Buchwald, 2001) and direct impacts via mortality (*i.e.* roadkill; Clevenger, Chruszcz & Gunson, 2003). Roads therefore pose a threat to the survival of individual animals and entire populations.

Here, we use a uniform protocol for roadkill data collection (Collinson, Parker, Bernard, Reilly & Davies-Mostert,2014), to document the species diversity of roadkill in the Greater Mapungubwe Transfrontier Conservation Area (GMTFCA), Limpopo province, South Africa. In addition, we assess the influence of season, road surface type and animal activity patterns on roadkill rates.

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METHODS

Our study area was the GMTFCA (Fig. 1) which falls within the sub-tropical region of South Africa and is in a dry Savanna subregion of the Mopane Bioregion (Schulze & McGee, 1978). The study area is characterized by hot (17–27°C) summers and mild (4–20°C) winters with occasional frost (Nel & Nel, 2009). The mean annual rainfall is 278 mm but can be as low as 154 mm during dry years and as high as 451 mm per annum during wetter years (Nel & Nel, 2009). The rainy season is predominantly from November to March (summer) when the province receives 90% of its total annual rainfall (M'Marete, 2003).

The area contains a high species richness of reptiles (~120 species; Branch, 1998), birds (≥429 species; Hockey, Dean & Ryan, 2005) and mammals (~100 species; Skinner & Chimimba, 2005), whilst amphibian species richness is low (~12 species; Braack, 2009). Several roads (paved and unpaved) traverse the area and elevated

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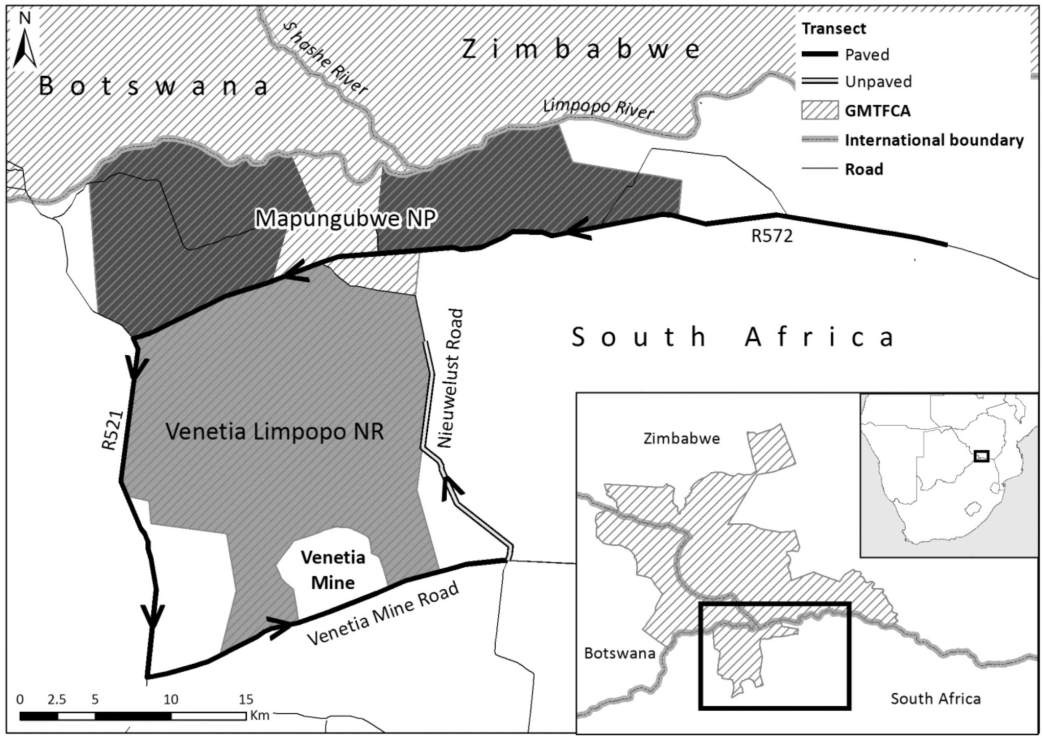

Fig. 1. The Greater Mapungubwe Transfrontier Conservation Area (GMTFCA), northern Limpopo province, South Africa, showing the roads sampled.

traffic volumes are anticipated as a result of expected increases in local mining and tourism activities (Collinson, 2013). Both road types are single-lane roads with an average width of 6 m (range = 4–8 m), and a maximum speed of 60 km/h on the unpaved roads and 120 km/h on the paved roads. Mean traffic volume for the paved roads was 149 vehicles per day (range = 74–228 vehicles, S.D. = 37.6) and 11 vehicles per day (range = 7–16 vehicles, S.D. = 3.92) for the unpaved roads. The roads are bordered on either side by fences which range in height between 1.2 m and 2.4 m, and with 3 to 23 of wire strands. Some of the fences are electrified.

We drove transects 1.5 hours after sunrise, at a speed of 40–50 km/h, using a single, trained observer (Collinson, Parker, Bernard, Reilly & Davies-Mostert, 2014). A 100 km section of paved road and a 20 km section of unpaved road were driven daily over three 40-day periods across the three ecological seasons (hot/dry; October/November 2011, hot/wet; February/March 2012 and cold/dry; June/July 2012) (modified from Viljoen, 1989; Viljoen *et al.,* 2008) from October 2011 to July 2012. Ecological seasons were selected over meteorological seasons because changes in animal behaviour (*e.g.* the timing of breeding) associated with these seasons were considered more likely to influence roadkill rates. Roadkill carcasses were only counted if they were detected on the road. Carcasses on road verges were excluded (Guinard, Julliard & Barbraud, 2012).

We divided roadkills into four vertebrate classes, amphibians, reptiles, birds and mammals, and a fifth category for roadkill that could not be identified to class level ('unknown'). Each roadkill was further assigned to order, family, genus and species (Branch, 1998; Hockey, Dean & Ryan, 2005; Skinner & Chimimba, 2005; Carruthers & du Preez, 2011).

Roadkill rates per day and per km were calculated for each class and the activity pattern of each species was classified as diurnal, nocturnal or crepuscular (Branch, 1998; Hockey, Dean & Ryan, 2005; Skinner & Chimimba, 2005; Carruthers & du Preez, 2011). A photograph, the position on the road, and GPS coordinates (Garmin eTrex) were taken for each carcass to avoid recounts on consecutive days.

All statistical analyses were conducted using

Statistica (v10, StatSoft, Inc. Tulsa, OK, U.S.A. 2011).

RESULTS

We drove a total of 14 400 km over 120 days (taking 498 hours to complete). Average transect duration was 180 minutes (range = 132–278 minutes) on the 100 km paved road and 33 minutes (range = 22–66 minutes) on the 20 km unpaved road.

Nine hundred and ninety-one roadkill items were observed on the 100 km paved road transect and 36 on the unpaved road. Carcasses comprised 162 species from 24 orders and 65 families; 93 carcasses could not be identified to species level (Table 1).

With all the data pooled for each road type, roadkill count was strongly influenced by road type and season (χ^2 = 11.40; d.f. = 2; P < 0.05). The proportion of roadkill was greatest in the hot/wet season (4.3 roadkill/km/day paved and 1.3 roadkill/km/day unpaved) and lowest in the cold/dry season (2.0 roadkill/km/day paved and 0.1 roadkill/km/day unpaved: Table 1).

Roadkill rates were highest for birds (1.5 roadkill/km paved and 0.2 roadkill/km unpaved; Table 2), lower but similar for reptiles (0.8 roadkill/km paved and 0.1 roadkill/km unpaved; Table 2) and mammals (1 roadkill/km paved and 0.2 roadkill/km unpaved) and lowest for amphibians (0.2 roadkill/km paved and 0.0 roadkill/km unpaved). Season had a significant effect on roadkill occurrence (one way ANOVA; $F_{(2,117)}$ = 19.04, P<0.05), with birds being more frequent than other taxonomic groups during the hot seasons, and mammals being more frequent during the cold/dry season (Table 2).

All amphibian and 62% of mammal roadkill species were nocturnal (Skinner & Chimimba, 2005; Carruthers & du Preez, 2011; Appendix 1). Reptile activity was more evenly balanced, with 47% of roadkill species being diurnal and 41% nocturnal (Branch, 1998). Most of the birds (80%) were diurnal (Hockey, Dean & Ryan, 2005).

Of the taxonomic groups occurring in the GMTFCA, 48% of the mammals in the area were commonly found as roadkill, followed by reptiles (28%), amphibians (27%), and birds (20%) (Appendix I). Of the three amphibian species detected as roadkill, the eastern olive toad (*Amientophynus garmani*) was the most abundant (86%; *n* = 41). The flap-neck chameleon (*Chameleo dilipsis*) was the most frequently recorded reptile species (19%; *n* = 45; Appendix 1). Eighty-five bird species were detected as roadkill with Helmeted Guineafowl (*Numida meleagris*) and the Nightjars (Caprimulgidae spp.) being the most frequently recorded (both 16%; *n* = 69). Scrub hares (*Lepus saxatilis*) accounted for almost 40% of all mammal roadkill (*n* = 300 individuals), followed by bushveld gerbils (*Gerbilliscus leucogaster*; 7%; *n* = 21) and African civets (*Civettictis civetta*; 5%;*n* =16; Appendix 1).

DISCUSSION

There is a paucity of data available for road ecology in Africa with only four previous studies focusing on roadkill (Siegfried, 1965, 1966; Eloff & van Niekerk, 2005, 2008; Bullock, Malan & Pretorius, 2011). Consequently, comparison of roadkill rates to other areas is difficult. However, broad, qualitative comparisons with global trends are possible.

Roadkill rates from our study were up to nine times higher (9.6 roadkill/100 km) for mammals (range = 0.06–8.6 roadkill/100 km; see Hell, Plavý, Slamečka & Gašparík, 2005; Smith-Patten & Patten, 2008) and up to 10 times higher for birds (10.46 roadkill/100 km), than other published studies (range = 0.007–1.14 roadkill/100 km; see Hell, Plavý, Slamečka & Gašparík, 2005; Bullock, Malan & Pretorius, 2011). This suggests that our study area has high mammal and bird species abundance. Data for amphibians and reptiles were more difficult to compare due to a paucity of studies on these groups. However, the number of amphibian and reptile roadkill recorded, suggests that roadkill numbers in the GMTFCA are still higher than other

Table 1. Number of roadkill detected in the GMTFCA, Limpopo province, South Africa, in 2011/12.

Season	Number of roadkill detected		Season totals
	100 km paved road	20 km unpaved road	
Hot/dry	376	9	385
Hot/wet	416	25	441
Cold/dry	199	2	201
Total	991	36	1027

Table 2. Roadkill rates for each vertebrate class detected across three ecological seasons in the GMTFCA, South Africa, on (**a**) paved and (**b**) unpaved roads (for identified species only.) The highest rate per taxon is highlighted in bold.

Taxa	Hot/dry			Hot/wet			Cold/dry			All seasons		
	No./km	No./day	No. of species	No./km	No./day	No. of species	No./km	No./day	No. of species	No./km	No./day	No. of species
(a) Paved												
Amphibians	**0.4**	**1.0**	2	0.1	0.2	2	0.0	0.0	0	0.2	0.4	3
Reptiles	0.9	2.3	22	**1.3**	**3.6**	27	0.1	0.2	7	0.8	2.0	34
Birds	1.4	3.4	49	**2.2**	**5.6**	52	0.8	2.0	21	1.5	3.7	81
Mammals	1.0	2.6	28	0.7	1.8	24	**1.0**	**2.8**	19	1.0	2.4	44
Total	3.7	9.3	101	4.3	11.2	105	2	5	47	3.4	8.5	162
(b) Unpaved												
Amphibians	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
Reptiles	0.0	0.0	0	**0.1**	**0.1**	2	0.0	0.0	0	0.1	0.0	2
Birds	0.3	0.1	4	**0.9**	**0.4**	11	0.0	0.0	0	0.2	0.2	16
Mammals	0.2	0.1	2	**0.3**	**0.2**	2	0.1	0.1	2	0.2	0.1	3
Total	0.5	0.2	9	1.3	0.7	25	0.1	0.1	2	0.5	0.3	36

studies (see Clevenger, Chruszcz & Gunson, 2003; MacKinnon, Moore & Brooks, 2005; Sutherland, Dunning & Baker, 2010), despite the GMTFCA not being an amphibian-rich site (Braack, 2009; Carruthers & du Preez, 2011).

Our study serves as a catalogue of roadkill species in one important conservation area of South Africa, and whilst supporting previous work which shows a seasonal effect on road mortality rates (Clevenger, Chruszcz & Gunson, 2001; Mkanda & Chansa, 2011; Bullock, Malan & Pretorius, 2011), further analysis of the determinants of roadkill is required. Seasons influence cycles of animal behaviour, with most activity occurring during the reproductive and dispersal periods (Branch, 1998; Hockey, Dean & Ryan, 2005; Skinner & Chimimba, 2005; Carruthers & du Preez, 2011). The hot/wet season in southern Africa falls between February and May (Viljoen *et al.,* 2008) and this is when animals are most active (Branch, 1998; Hockey, Dean & Ryan, 2005; Skinner & Chimimba, 2005; Carruthers & du Preez, 2011), particularly near roads (Mkanda & Chansa, 2011), and is when road wildlife mortality rates increase (Clevenger, Chruszcz & Gunson, 2001).

It is important that future road ecology studies in South Africa expand the inventory of species at risk from roads. Animals are killed on roads, often irrespective of their taxonomic group. This highlights the need for further studies which examine trends relative to the country's economic development (such as mining and tourism, both of which require an extensive transport infrastructure).

Prolific and abundant roadkill species in the GMTFCA (such as eastern olive toad, flap-neck chameleon, Helmeted Guineafowl and scrub hare; Skinner & Chimimba, 2005; Appendix 1), often result in a cascade effect along the trophic hierarchy where scavenging animals seek out roadkill and often become roadkill themselves (Antworth, Pike & Stevens, 2005; Dean & Milton, 2003). Furthermore, body size is often an excellent indicator of vulnerability to becoming roadkill (Barthelmess & Brooks, 2010). For example, over one third of rodent species were found to have a high incidence of roadkill in total numbers in the GMTFCA (Appendix 1), but the impact on the population may be less than for a large mammal species, such as the African civet (that had 16 road mortalities recorded; Appendix 1) where reproductive rates are much slower and litter size is smaller (Feldhamer, 2007). This can have important con-

servation implications for species that are 'vulnerable', when coupled with other threats alongside roadkill. However, future work should not be limited to species categorised currently as 'at threat' since cumulative impacts on populations over time may be far-reaching.

Roadkill occurrence data can provide information about the potential impacts of roads across different taxa, and can serve as a benchmark for monitoring such impacts in the face of changing land-use. Furthermore, roadkill data provides secondary opportunities to contribute towards national and regional biodiversity inventories and local species checklists.

CONCLUSION

Globally, road ecology research has gained in momentum since the 1980s. However, current South African legislative guidelines are inadequate for incorporating the indirect and direct effects of roads or their cumulative effects on local fauna. Despite roadkill databases being developed for South Africa, simply counting the number of dead animals on the road will not inform whether roads and vehicles are endangering the existence of populations or species (van der Ree, Jaeger, van der Grift & Clevenger, 2011). More intensive research is recommended to examine how and to what extent variables (such as season, habitat type and traffic volume) interact. The determinants of roadkill also need to be better understood to enable decisions to be made in designing roads (Taylor & Goldingay, 2010; van der Ree, Jaeger, van der Grift & Clevenger, 2011). While roadkill data are yet to be used in South African road planning, related concerns include gathering roadkill data (in the form of species inventories), undertaking risk assessments, identifying, developing and implementing relevant mitigation strategies, and raising awareness with transportation and planning agencies.

Currently, no significant safeguards have been applied to mitigate the impacts of roads on wildlife. South Africa is fundamentally different to Europe and North America in its faunal diversity, landscapes and geography, density of roads and humans, and funding and support for road ecology research and mitigation. However, the information and lessons learned in developed countries can be implemented and adapted in order to develop unique African solutions.

A balance between the need for an efficient transport network, improved road safety for motorists and a sustainable environment is a challenge facing most developing nations. This commitment will require financial resources and a legislative framework to support the implementation of mitigation measures.

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Appendix 1. Species of vertebrate roadkill detected over three ecological seasons on a 100 km section of paved road and a 20 km section of unpaved road in the GMTFCA, South Africa. Activity: C = Crepuscular, D = Diurnal, N = Nocturnal, B = Both diurnal and nocturnal, U = Unknown; Branch, 1998; Hockey, Dean & Ryan, 2005; Skinner & Chimimba, 2005; Carruthers & du Preez, 2011). Species are ranked in order of frequency of occurrence within each taxon.

Class	No.	Order	Family	Scientific name	Common name	Activity	Hot/dry	Hot/wet	Cold/dry	Total
Amphibia	1	Anura	Bufonidae	*Amietophrynus garmani*	eastern olive toad	N	37	4	0	41
	2	Anura	Rhacophorinae	*Chiromantis xerampalena*	southern foam nest frog	N	2	0	0	2
	3	Anura	Breviciptidae	*Breviceps adspersus*	bushveld rain frog	N	0	1	0	1
	4	Anura	Unknown	*Unknown*	unidentified frog	U	1	2	0	3
Reptilia	1	Squamata	Chamaeleonidae	*Chamaeleo dilepsis*	flap-neck chameleon	D	4	41	0	45
	2	Squamata	Elapidae	*Naja mossambica*	Mozambique spitting cobra	N	7	15	2	24
	3	Squamata	Colubridae	*Lamprophis fuliginosus*	brown house snake	N	9	13	0	22
	4	Squamata	Gerrhosauridae	*Gerrhosaurus nigrolineatus*	black-lined plated lizard	D	9	9	0	18
	5	Squamata	Viperidae	*Bitus caudalis*	horned adder	C	6	6	2	14
	6	Squamata	Viperidae	*Causus rhombeatus*	rhombic night adder	N	8	5	0	13
	7	Squamata	Atractaspididae	*Atractaspis bibronii*	Bibron's burrowing asp	N	4	6	0	10
	8	Squamata	Colubridae	*Prosymna sundevalli*	Sundevall's shovel-snout	N	7	2	0	9
	9	Squamata	Colubridae	*Psammophis subtaeniatus*	stripe-bellied sand snake	D	7	2	0	9
	10	Squamata	Agamidae	*Agama armata*	Peter's ground agama	D	8	1	0	9
	11	Squamata	Colubridae	*Dasypeltis scabra*	rhombic egg eater	N	4	2	0	6
	12	Squamata	Lacertidae	*Nucras intertexta*	spotted sandveld lizard	C	4	0	1	5
	13	Squamata	Atractaspididae	*Atractaspis duerdeni*	Duerden's burrowing asp	N	0	4	0	4
	14	Squamata	Viperidae	*Bitis arientans arientans*	puff adder	C	1	3	0	4
	15	Squamata	Varanidae	*Varanus albigularia albigularis*	rock monitor	D	1	3	0	4
	16	Testudines	Testudinidae	*Geochelone pardalis*	leopard tortoise	D	1	2	0	3
	17	Squamata	Boidae	*Python natalensis*	southern African python	D	0	3	0	3
	18	Squamata	Colubridae	*Dispholidu stypus*	boomslang	D	0	3	0	3
	20	Squamata	Colubridae	*Rhamphiophi srostratus*	rufous beaked snake	D	0	2	1	3
	21	Squamata	Colubridae	*Telescopus semiannulatus*	eastern tiger snake	N	1	1	1	3
	22	Testudines	Pelomedusidae	*Pelusios sinuatus*	serrated hinged terrapin	D	0	2	0	2
	23	Squamata	Atractaspididae	*Xenocalamus transvaalensis*	transvaal quill-snouted snake	D	1	1	0	2
	24	Squamata	Colubridae	*Prosymna bivittata*	two-striped shovel snout	N	1	1	0	2
	25	Squamata	Elapidae	*Dendroaspis polyelpis*	black mamba	D	0	2	0	2
	26	Squamata	Elapidae	*Najaan nulifera*	snouted cobra	N	2	0	0	2
	27	Squamata	Gekkonidae	*Chondrodactylus turneri*	Turner's thick-toed gecko	N	2	0	0	2
	28	Squamata	Colubridae	*Mehelya nyassae*	black file snake	N	0	1	0	1
	29	Squamata	Colubridae	*Philothamnus semivariegatus*	spotted bush snake	D	0	1	0	1
	30	Squamata	Colubridae	*Psammophis mossambicus*	olive grass snake	D	0	1	0	1
	31	Squamata	Colubridae	*Pseudas piscana*	mole snake	N	1	0	0	1

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Appendix 1 (continued)

Class	No.	Order	Family	Scientific name	Common name	Activity	Hot/dry	Hot/wet	Cold/dry	Total
	32	Squamata	Elapidae	*Elapsoidea boulengeri*	Boulenger's garter snake	N	0	1	0	1
	33	Squamata	Lacertidae	*Heliobolus lugubrisus*	bushveld lizard	D	1	0	0	1
	34	Squamata	Lacertidae	*Pedioplanis lineoocellata*	spotted sand lizard	C	0	0	1	1
	35	Squamata	Unknown	*Unknown*	unidentified snake	U	2	0	0	2
	36	Squamata	Unknown	*Unknown*	unidentified reptile	U	0	1	0	1
Aves	1	Galliformes	Numididae	*Numida meleagris*	Helmeted Guineafowl	C	18	44	7	69
	2	Strigiformes	Caprimulgidae	*Caprimulgus rufigena*	Rufous-cheeked Nightjar	N	10	17	1	28
	3	Passeriformes	Malaconotidae	*Tchagra senegala*	Black-crowned Tchagra	D	1	0	20	21
	4	Strigiformes	Caprimulgidae	*Unknown*	Unidentified Nightjar	N	4	9	2	15
	5	Passeriformes	Fringillidae	*Emberiza tahapisi*	Cinnamon-breasted Bunting	D	1	13	0	14
	6	Galliformes	Phasianidae	*Pternisris natalensis*	Natal Spurfowl	D	4	5	4	13
	7	Passeriformes	Hirundinidae	*Hirundo rustica*	Barn Swallow	D	3	9	0	12
	8	Passeriformes	Alaudidae	*Mira frasabota*	Sabota Lark	D	2	7	3	12
	9	Galliformes	Phasianidae	*Dendroperdix sephaena*	Crested Francolin	D	1	3	5	9
	10	Bucertiformes	Bucerotidae	*Tockus leucomelas*	Southern Yellow-billed Hornbill	D	1	2	5	8
	11	Strigiformes	Strigidae	*Bubo africanus*	Spotted Eagle Owl	N	1	6	1	8
	12	Strigiformes	Caprimulgidae	*Caprimulgus pectoralis*	Fiery-necked Nightjar	C	3	5	0	8
	13	Strigiformes	Caprimulgidae	*Caprimulgus europaeus*	European Nightjar	N	0	8	0	8
	14	Columbiformes	Columbida	*Streptopelia senegalensis*	Laughing Dove	D	6	2	0	8
	15	Charadriiformes	Burhinidae	*Burhinus capensis*	Spotted Thick Knee	N	3	5	0	8
	16	Passeriformes	Ploceidae	*Quelea quelea*	Red-billed Quelea	D	7	1	0	8
	17	Passeriformes	Estrildidae	*Pytilia melba*	Green-winged Pytilia	D	1	1	6	8
	18	Gruiformes	Otididae	*Lophotis ruficrista*	Red-crested Korhaan	D	4	3	0	7
	19	Passeriformes	Malaconotidae	*Tchagra australis*	Brown-crowned Tchagra	D	4	2	0	6
	20	Passeriformes	Hirundinidae	*Hirundo abyssinica*	Lesser-striped Swallow	D	6	0	0	6
	21	Passeriformes	Fringillidae	*Emberiza capensis*	Golden-breasted Bunting	D	0	5	1	6
	22	Columbiformes	Columbidae	*Streptopelia*	Unidentified Dove	D	3	0	2	5
	23	Passeriformes	Ploceidae	*Plocepasser mahali*	White-browed Sparrow-Weaver	D	0	4	1	5
	24	Passeriformes	Estrildidae	*Uraeginthus angolensis*	Blue waxbill	D	3	1	1	5
	25	Coraciiformes	Coraciidae	*Coracias caudatus*	Lilac-breasted Roller	D	0	4	0	4
	26	Strigiformes	Caprimulgidae	*Caprimulgus tristigma*	Freckled Nightjar	N	0	4	0	4
	27	Strigiformes	Caprimulgidae	*Caprimulgus fossii*	Square-tailed Nightjar	N	0	4	0	4
	28	Strigiformes	Caprimulgidae	*Macrodipteryx vexillarius*	Pennant-winged Nightjar	N	0	4	0	4
	29	Columbiformes	Columbidae	*Streptopelia capicola*	Cape Turtle Dove	C	4	0	0	4
	30	Passeriformes	Cisticolidae	*Cisticola*	Unidentified Cisticola	D	1	0	3	4
	31	Passeriformes	Ploceidae	*Anaplectes melanotis*	Red-headed Weaver	D	3	1	0	4

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Appendix 1 (continued)

Class	No.	Order	Family	Scientific name	Common name	Activity	Hot/dry	Hot/wet	Cold/dry	Total
	32	Galliformes	Phasianidae	*Coturnix coturnix*	Common Quail	D	1	2	0	3
	33	Bucertiformes	Bucerotidae	*Tockus erythrohynchus*	Red-billed Hornbill	D	0	2	1	3
	34	Coraciiformes	Coraciidae	*Coracias garrulus*	European Roller	D	0	3	0	3
	35	Culcliformes	Centropodidae	*Centropus burchelii*	Burchell'sCoucal	D	1	1	1	3
	36	Strigiformes	Strigidae	*Glaucidium perlatum*	Pearl-spotted Owlet	N	1	0	2	3
	37	Columbiformes	Columbidae	*Oena capensis*	Namaqua Dove	D	2	1	0	3
	38	Passeriformes	Malaconotidae	*Prionops plumatus*	White-crested Helmet Shrike	D	1	2	0	3
	39	Passeriformes	Laniidae	*Lanius collurio*	Red-backed Shrike	D	0	3	0	3
	40	Passeriformes	Laniidae	*Eurocephalus anguitimens*	Southern White-crowned Shrike	D	0	3	0	3
	41	Passeriformes	Ploceidae	*Sporopipes squamifrons*	Scaly-feathered Finch	D	2	0	1	3
	42	Passeriformes	Estrildidae	*Amadina fasciata*	Cut-throat Finch	D	2	1	0	3
	43	Passeriformes	Passeridae	*Passer diffusus*	Southern Grey-headed Sparrow	D	3	0	0	3
	44	Turniciformes	Turnicidae	*Turnix sylvatica*	Kurrichane Button-quail	C	1	0	1	2
	45	Coraciiformes	Meropidae	*Merops nubicoides*	Southern Carmine Bee-eater	D	0	7	0	2
	46	Strigiformes	Tytonidae	*Tyto alba*	Barn Owl	N	0	2	0	2
	47	Columbiformes	Columbidae	*Streptopelia decipiens*	Red-eyed Dove	D	1	1	0	2
	48	Charadriiformes	Glareolidae	*Rhinoptilus chalcopterus*	Bronze-Winged Courser	N	0	2	0	2
	49	Passeriformes	Corvidae	*Corvus albus*	Pied Crow	D	1	1	0	2
	50	Passeriformes	Sylviidae	*Eromomela icteropygialis*	Yellow-bellied Eremomela	D	0	1	1	2
	51	Passeriformes	Cisticolidae	*Prinia flavicans*	Black-chested Prinia	D	0	1	1	2
	52	Passeriformes	Muscicapidae	*Cercotrichas leucophrys*	White-browed Scrub Robin	D	1	1	0	2
	53	Passeriformes	Passeridae	*Petronia superciliaris*	Yellow-throated Petronia	D	0	2	0	2
	54	Passeriformes	Fringillidae	*Serinus atrogularis*	Black-throated Canary	D	2	0	0	2
	55	Piciformes	Lybiidae	*Tricholaema leucomelas*	Acacia Pied Barbet	D	0	0	1	1
	56	Coraciiformes	Coraciidae	*Coracia snaevia*	Purple Roller	D	1	0	0	1
	57	Coraciiformes	Dacelonidae	*Halcyon senegalensis*	Woodland Kingfisher	D	1	0	0	1
	58	Coraciiformes	Dacelonidae	*Halcyon albiventris*	Brown Hooded Kingfisher	D	1	0	0	1
	59	Coraciiformes	Meropidae	*Mero pspusillus*	Little Bee-Eater	D	0	1	0	1
	60	Coraciiformes	Meropidae	*Mero psapiaster*	European Bee-eater	D	1	0	0	1
	61	Strigiformes	Strigidae	*Strix woodfordii*	African Wood Owl	N	1	0	0	1
	62	Columbiformes	Columbidae	*Turtur chalcospilos*	Emerald Spotted Wood Dove	D	1	0	0	1
	63	Gruiformes	Otididae	*Ardeoti skori*	Kori Bustard	D	1	0	0	1
	64	Charadriiformes	Charadriidae	*Chadradius tricollaris*	Three-banded Plover	B	1	0	0	1
	65	Falconiformes	Accipitridae	*Accipiter tachiro*	African Goshawk	D	0	1	0	1
	66	Falconiformes	Accipitridae	*Buteo vulpinus*	Steppe Buzzard	D	0	1	0	1
	67	Falconiformes	Accipitridae	*Aquila wahlbergi*	Wahlberg's Eagle	D	1	0	0	1
	68	Passeriformes	Malaconotidae	*Tchagra*	Unidentified Tchagra	D	0	0	1	1

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Appendix 1 (continued)

Class	No.	Order	Family	Scientific name	Common name	Activity	Hot/dry	Hot/wet	Cold/dry	Total
	69	Passeriformes	Malaconotidae	*Batismolitor*	Chinspot Batis	D	0	0	1	1
	70	Passeriformes	Paridae	*Anthoscopus minutus*	Cape Penduline-Tit	D	1	0	0	1
	71	Passeriformes	Paridae	*Anthoscopus caroli*	Grey Penduline Tit	D	0	1	0	1
	72	Passeriformes	Sylviidae	*Sylvietta rufescens*	Long-billed Crombec	D	1	0	0	1
	73	Passeriformes	Cisticolidae	*Cisticola chiniana*	Rattling Cisticola	D	0	0	1	1
	74	Passeriformes	Cisticolidae	*Cisticola aridulus*	Desert Cisticola	D	0	1	0	1
	75	Passeriformes	Cisticolidae	*Heliolais erythropterus*	Red-winged Warbler	D	0	1	0	1
	76	Passeriformes	Alaudidae	*Unknown*	Unidentified Lark	D	0	0	1	1
	77	Passeriformes	Muscicapidae	*Psophocichla litsitsirupa*	Groundscraper Thrush	D	1	0	0	1
	78	Passeriformes	Muscicapidae	*Melaenorni spammelaina*	Southern Black Flycatcher	D	0	1	0	1
	79	Passeriformes	Nectariniidae	*Cinnyris talatala*	White-bellied Sunbird	D	1	0	0	1
	80	Passeriformes	Ploceidae	*Quelea erythrops*	Red-headed Quelea	D	0	0	1	1
	81	Passeriformes	Estrildidae	*Granatin agrantina*	Violet-eared Waxbill	D	0	1	0	1
	82	Passeriformes	Estrildidae	*Logonosticta senegala*	Red-billed Fire Finch	D	1	0	0	1
	83	Passeriformes	Passeridae	*Passer domesticus*	House Sparrow	D	1	0	0	1
	84	Passeriformes	Fringillidae	*Crithagramo zambica*	Yellow-fronted Canary	D	0	1	0	1
	85	Passeriformes	Fringillidae	*Crithagra flaviventris*	Yellow Canary	D	0	1	0	1
	86	Unknown	Unknown	*Unknown*	Unidentified Bird	U	9	5	3	17
Mammalia	1	Lagomopha	Leporidae	*Lepus saxatilis*	scrub hare	N	37	26	55	118
	2	Rodentia	Muridae	*Gerbilliscus leucogaster*	bushveld gerbil	N	4	7	10	21
	3	Rodentia	Unknown	*Unknown*	unidentified rodent	U	13	2	1	16
	4	Carnivora	Viverridae	*Civettictis civetta*	African civet	N	4	3	9	16
	5	Ruminantia	Bovidae	*Unknown*	unidentified antelope	U	1	2	8	11
	6	Rodentia	Muridae	*Aethomys chrysophilus*	red veld rat	N	6	4	0	10
	7	Rodentia	Sciuridae	*Xerus inauris*	southern African ground squirrel	D	3	4	0	7
	8	Rodentia	Hystricidae	*Hystrix africaeaustralis*	Cape porcupine	N	2	1	3	6
	9	Rodentia	Pedetidae	*Pedetes capensis*	springhare	N	1	0	5	6
	10	Chiroptera	Rhinolophidae	*Rhinolophus fumigatus*	Ruppell's horseshoe bat	N	1	4	1	6
	11	Carnivora	Canidae	*Canis mesomelas*	black-backed jackal	B	2	1	3	6
	12	Carnivora	Herpestidae	*Galerella nigrata*	slender mongoose	D	2	0	3	5
	13	Rodentia	Muridae	*Mus minutoides*	pygmy mouse	N	4	0	0	4
	14	Rodentia	Muridae	*Micaelamys namaquensis*	Namaqua rock mouse	N	2	2	0	4
	15	Carnivora	Canidae	*Octocyon megalotis*	bat-eared fox	B	0	2	2	4
	16	Primates	Cercopithecidae	*Papio hamadryas*	chacma baboon	D	1	1	1	3
	17	Eulipotyphla	Soricidae	*Crocidura hirta*	lesser red musk shrew	B	2	1	0	3
	18	Ruminantia	Bovidae	*Sylvicapra grimmia*	common duiker	D	0	0	3	3

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Appendix 1 (continued)

Class	No.	Order	Family	Scientific name	Common name	Activity	Hot/dry	Hot/wet	Cold/dry	Total
	19	Ruminantia	Bovidae	*Raphicerus campestris*	steenbok	D	2	0	1	3
	20	Rodentia	Sciuridae	*Paraxerus cepapi*	tree squirrel	C	0	2	0	2
	21	Rodentia	Muridae	*Lemniscomys rosalia*	single striped mouse	D	1	0	1	2
	22	Rodentia	Muridae	*Steatomys pratensis*	fat mouse	N	2	0	0	2
	23	Primates	Galagidea	*Otolemur crassicaudatus*	greater galago	N	0	1	1	2
	24	Chiroptera	Nycteridae	*Nycteris thebaica*	Egyptian slit-faced bat	N	1	1	0	2
	25	Carnivora	Hyaenidae	*Proteles cristatus*	aardwolf	N	0	1	1	2
	26	Carnivora	Hyaenidae	*Hyaena brunnea*	brown hyaena	N	1	0	1	2
	27	Suiformes	Suidae	*Phacochoerus africanus*	warthog	D	1	1	0	2
	28	Ruminantia	Bovidae	*Tragelaphus strepsiceros*	greater kudu	D	0	0	2	2
	29	Macroscelidea	Macroscelididae	*Elephantuls intufi*	bushveld elephant shrew	C	1	0	0	1
	30	Rodentia	Bathyergidae	*Cryptomys hottentotus*	African mole-rat	N	0	1	0	1
	31	Rodentia	Muridae	*Acomys spinosissimus*	spiny mouse	N	0	1	0	1
	32	Rodentia	Muridae	*Mastomys natalensis sensu lato*	natal multimammate mouse	N	0	1	0	1
	33	Rodentia	Muridae	*Otomys irroratus sensu lato*	vlei rat	C	0	1	0	1
	34	Rodentia	Muridae	*Cricetomys gambianus*	Gambian giant rat	N	1	0	0	1
	35	Rodentia	Muridae	*Saccostomus campestris*	pouched mouse	N	1	0	0	1
	36	Rodentia	Muridae	*Rattus rattus*	black rat	N	0	1	0	1
	37	Primates	Galagidea	*Galag omoholi*	South African galago	N	1	0	0	1
	38	Carnivora	Hyaenidae	*Crocuta crocuta*	spotted hyaena	N	1	0	0	1
	39	Carnivora	Felidae	*Caracal caracal*	caracal	N	0	0	1	1
	40	Carnivora	Felidae	*Felis lybica*	African wild cat	N	1	0	0	1
	41	Carnivora	Felidae	*Felis silvestris catus.*	domestic cat	D	1	0	0	1
	42	Carnivora	Viverridae	*Genetta tigrina*	South African large-spotted genet	N	0	0	1	1
	43	Carnivora	Herpestidae	*Mungos mungo*	banded mongoose	D	0	1	0	1
	44	Carnivora	Canidae	*Mellivora capensis*	honey badger	N	1	0	0	1
	45	Carnivora	Canidae	*Canis domesticus*	domestic dog	D	0	0	1	1
	46	Ruminantia	Bovidae	*Aepyceros melampus*	impala	D	0	1	0	1
	1	Unknown	Unknown	Unknown	unidentified mammal	U	12	0	0	12