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Sensitivity of Africa's larger mammals to humans

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Abstract

Habitat loss and overexploitation are driving differential declines in vertebrate taxa but variation in responses means it is often difficult to determine where to place conservation effort. Here we present an easy-to-use method to rank the relative sensitivities of the larger mammals of savanna Africa to human activities in order to prioritize conservation activities. We first made coarse predictions about susceptibility based on species' intrinsic ecological traits. Next we determined actual presence of these species using transect surveys within the heavily impacted Wami-Mbiki Wildlife Management Area in Tanzania, by conducting interviews outside this protected area, and monitoring changes in populations within both of these zones. Finally we used these combined data to derive a sensitivity measure than we compared to prior predictions about the susceptibility. Our empirical measure of sensitivity to humans was positively correlated with species' body mass, and home range size. The empirical data allowed us to categorize these species into those that are very sensitive to humans (*species in danger*), sensitive to humans (*human avoiders*), moderately common species (*human adapters*), and those that are positively impacted by people (*human exploiters*). . Conservation efforts aimed at *human avoiders* and *species in danger* are likely to have disproportionate payoffs in protecting larger mammal assemblages in Africa as these more sensitive species likely act as focal species (*sensu* Lambeck 1997) for management efforts. Our measures combine easy-to-conduct transect data with interview data, and evaluate temporal changes to reach conclusions about how sensitive large mammals are to humans. These methods can be applied in other regions where studies are beginning to examine wildlife declines outside protected areas.

Keywords:-conservation prioritization, focal species, Tanzania, Wami-Mbiki Wildlife Management Area

Introduction

Anthropogenic pressures, principally habitat loss and overexploitation, are driving vertebrate declines (Butchart et al. 2010) in major taxa (amphibians, Stuart et al. 2004; birds, Gaston et al. 2003; mammals, Ceballos & Ehrlich 2002; reptiles, Gibbons et al. 2000) making it difficult to know where to direct conservation effort. Since species do not all respond to humans equally (Blair 1996; McKinney 2002), it may be expeditious to focus conservation on the most sensitive taxa. In the past, conservation biologists have classified species along a spectrum of vulnerability to humans. At one end of the spectrum are *avoiders* that are intolerant of any human presence; at the other are *exploiters*, species that are not impacted by people or that even benefit from anthropogenic modifications to the landscape. Between these extremes are *adapters*, species that persist in the face of anthropogenic pressure and land conversion but not without suffering some negative impact. These insights are derived from studies of species diversity across urban gradients for birds (Blair 1996), butterflies (Blair & Launer 1997), reptiles (Germaine & Wakeling 2001), and mammalian carnivores (Crooks 2002) all primarily in North America or Europe (McKinney 2008), although also for birds in South Africa (van Rensburg et al. 2009). To date, no study has classified the larger mammals of savanna Africa along this same spectrum of sensitivity to humans. In part, this is because very few studies have explicitly examined wildlife declines outside protected areas in East Africa, making it difficult to predict the fate of mammals in anthropogenic landscapes that are increasing so rapidly across the continent.

Sub-Saharan Africa has the fastest growing human population of any region in the world (Population Reference Bureau 2016) resulting in rapid conversion of natural landscapes to human use (Hansen et al. 2013; Brink et al. 2014; Vittek et al. 2014; Jacobson et al. 2015). Concomitantly, large mammal declines have been observed in many places (e.g., Brashares et al. 2001; Stoner et al. 2006; Craigie et al. 2010; Bouché et al. 2012; Ogutu et al. 2016) driven by habitat loss stemming from land conversion to agriculture and livestock grazing (Newmark 2008; Western et al. 2009; Kinnaird & O'Brien 2012), over-hunting for bushmeat (Brashares et al. 2004; Abernethy et al. 2013; Lindsey et al. 2013) and retaliatory and ritual killing of predators (Kissui 2008; Hazzah et al. 2009; Ogada 2014). While these changes are principally occurring outside of reserves, even protected areas have not been spared (Craigie et al. 2010).

To assess the impact of humans on wildlife, researchers use methods such as transect surveys and interviews to study the presence and relative abundance of species in protected and unprotected landscapes. Transect surveys are ideal for gathering presence data on species that are easily observable in the field and can provide accurate population trend data for species that are reasonably common. However, transect surveys may miss difficult-to-detect species (those that are nocturnal or rare), and can overestimate population declines where species have changed their behavior to avoid hunting pressure. Interviews, in contrast, can provide data on rare species that are sighted infrequently by people who are present in a region year-round. However, interviews may be biased by misidentifications and by over-reporting of species that have not been seen for long periods of time. Thus, relying on only one type of data may be foolhardy. Combining these two types of data from these two methods offers a novel means to mitigate their limitations when assessing the status of large mammal species.

Researchers and wildlife managers often use particular species to focus conservation efforts (Lambeck 1997; Caro 2010). Lambeck (1997) defined "focal species" as a subset of species in a region that are grouped based on their susceptibility to different threats (e.g., habitat loss, habitat fragmentation, disturbance, or invasive species). More specifically, certain intrinsic ecological traits of species, such as trophic level, dispersal ability, habitat specialization, as well as body size and rarity, are associated with sensitivity to habitat loss and fragmentation (Henle et al. 2004; Ewers & Didham 2006). Using these traits, researchers can try to predict which species are most likely to suffer negative impacts of anthropogenic change, and to select focal species for conservation management (Amici & Battisti 2009; Battisti & Luiselli 2011). Assuring the ecological and anthropogenic conditions that allow persistence of the most susceptible species (i.e., focal species) can therefore result in the conservation of much biodiversity in a region. It follows that identification of large mammals that are most likely to decline in the face of human pressure (i.e., *human avoiders*) is important as they may act as focal species for conservation. Here we tested if particular large African mammals (LAMs) can be used as "focal species" in conservation by using both ecological variables from the literature to predict susceptibility and new data to assess sensitivity in an area of rapidly changing land use.

Materials and Methods

Study area

Our data collection took place around Wami-Mbiki Wildlife Management Area in Morogoro, Pwani and Tanga Regions, eastern Tanzania. Wami-Mbiki was chosen because it is part of a heterogeneous matrix of natural and converted lands; it represents a wide variety of environmental conditions as it sits at the confluence of three biomes (East African Coast, Somali-Maasai, and Zambezian); and is centrally located between several large protected areas (Mikumi and Saadani National Parks and Selous Game Reserve), Forest Reserves, and Game Controlled Areas. As a result, this area acts as a stepping-stone linking these protected areas together (Riggio and Caro 2017). At the center of this ecosystem is the Wami-Mbiki Wildlife Management Area; a multi-use community-based conservation area managed by the Wami-Mbiki Society and composed of an approximately 2,500 km^2 "core area," and a 1,500 km^2 "buffer zone" containing 24 member villages and farmland (TAWIRI 2009) (Fig. 1). Our second reason to choose this area is that the state of wildlife in Wami-Mbiki Wildlife Management Area is precarious due to the loss of external funding in 2010 when the Danish Hunters Association (http://www.jaegerforbundet.dk/) ended their financial support. A lack of funding for patrols within the area resulted in agricultural expansion, illegal timber logging, and wildlife poaching – all common anthropogenic pressures in Africa.

Species susceptibilities based on body size, home range size, niche breadth and trophic level

Our study focuses on 26 extant mammal species found in and around Wami-Mbiki, in addition to two species likely extirpated from the region (Table 1). Before the study began, however, we predicted that large-bodied species and those requiring large home ranges would suffer the greatest declines both inside and outside the Wildlife Management Area as both body mass and home range size are positively correlated with extinction risk across mammals (Woodroffe & Ginsberg 1998; Cardillo et al. 2005; Cardillo et al. 2008; Davidson et al. 2009), particularly in the tropics (Fritz et al. 2009). Based on known traits associated with species-level sensitivity to habitat loss and fragmentation, we also predicted that species in a high trophic level (i.e., predators), those with a narrow niche breadth, and that showed high rarity would be likely to experience population declines and/or local extirpations as well (Henle et al. 2004; Ewers & Didham 2006). We use home range size as a proxy for rarity, as species with larger home ranges will require more area to support each individual, thus resulting in a lower number of individuals in the same area than species with smaller home ranges. The relationship between home range size and rarity might be less strong for social mammals or those that exhibit "herd" behavior, as a greater number of individuals occupy the same sized home range. Thus, before the study started, we used a conceptual framework for predicting which species would likely act as focal species for conservation planning in savanna ecosystems in sub-Saharan Africa (Amici & Battisti 2009) based on four intrinsic ecological traits of the 28 study species (body size, home range size, niche breadth and trophic level).

To create a body size rank, we assigned the largest species (those in the top third of average body mass) a value of 3 and the smallest species (those in the bottom third of average mass) a value of 1. Intermediate species were assigned a value of 2. Similarly for home range size, we divided species into the bottom third (1), intermediate (2) and top third (3) average home range size. For niche breadth we classified species as generalists (1) if they are known to use all three major habitat types in and around Wami-Mbiki (grassland, woodland, and closed forest), intermediate (2) if they generally avoided one of these habitat types, and specialist (3) if they primarily use only one habitat type. Finally, we classified species as primarily herbivores (1), omnivores (2), or predators (3) to rank their respective trophic level. We summed these simple values across all four traits, resulting in a total predicted susceptibility to humans (Table 1).

Species sensitivities: Transects surveys

To determine whether these coarse *a priori* sensitivity classifications were indicative of species' population sizes, we wanted to record mammal presence and relative abundance empirically within the Wildlife Management Area. Therefore JR and FM walked 31 transects between 14th September and 15th October 2014 based on a stratified survey design of potential transect start points located at a distance of 10 km apart throughout the core area (Fig. 2). We walked a transect if it was fully contained within the Wildlife Management Area boundary, did not cross the Wami River, and was within 2 km of a drivable track.

Data collection started between 06:30 and 08:00am and transects were 12 km in length, structured as a triangle 4 km on each side (372 km of surveyed transect in total). Closed circuit transect designs have the advantage of starting and ending at the same location, and are logistically optimal in regions lacking an extensive road network (Waltert et al. 2008). To assess mammal species presence and relative abundance we used a direct observation survey technique (Buckland et al. 2001). We also recorded large mammal presence along each transect by noting all animal signs, by identifying footprints and dung to species level in the field on encountering them with the help of Wami-Mbiki Game Scouts.

We compared species' abundance data from this survey (2014) to a transect survey conducted by the Tanzania Wildlife Research Institute from 8th to 19th October 2009 (TAWIRI 2009). This survey consisted of 36 transects, arranged as straight paths 7.5 km in length (270 km in total). Although survey effort in 2014 was 38% higher than in 2009, the 2014 species rarefaction curve plateaus off at a lower cumulative number of species than that for 2009, while the 2009 rarefaction curve never plateaus, suggesting more species could have been found during the first survey with additional sampling effort (Fig. 3). These curves clearly illustrate that there were a fewer total number of species in 2014 than in 2009, despite greater sampling effort. Each transect was walked twice daily (morning and evening). However, to keep the data as comparable as possible, we compare the 2014 survey to the morning transects only. For both surveys we summed the number of individuals seen on all transects for each species (i.e., direct observations) and divided by the number of kilometers walked in total; thus the number of observed individuals per kilometer.

Species sensitivities: Interviews

Our second method of assessing species' sensitivities was through face-to-face interviews. In January and November 2014, JR and FM conducted semi-structured interviews in Swahili concerning large mammal presence in 65 villages surrounding the Wildlife Management Area (Fig. 1). For each survey we first gained the permission of the Village Executive Officer and/or Village Chairperson to conduct interviews with members of the Village Natural Resource Committee or Village Game Scouts (mean number of participants = 3.8, median = 3, range = 1 to 9). Nearly all villages (94%) had more than one participant, thereby reducing the possibility of relying on one individual's experience or skill in observing large mammal species' presence nearby the village. We introduced our research to the potential participants and gained their consent before proceeding. The Village Executive Office and/or Village Chairperson were usually present and participating in the interview. Interview questions included, (i) "Which animals do you see around your village", (ii) "In which season do you see this animal? (wet, dry, or both)", (iii) "In what direction and how far from here? (show map)", and (iv) "How often do you see them? (daily, monthly, once per year, or less frequently)". We also included interview data from 15 villages between the Wildlife Management Area and Saadani National Park (Van de Perre et al. 2014) generating species' data from a total of 80 villages around Wami-Mbiki Wildlife Management Area (Fig. 1). We compared species' presence data from interviews conducted in 2009 in the 24 villages in the Wami-Mbiki Society (Danielsen 2008) to those conducted during this survey (2014) in the same 24 member villages to generate population trends.

Fieldwork and interviews were conducted under the authority of the Tanzania Wildlife Research Institute, Wildlife Division, and the Commission for Science and Technology (COSTECH) (Research Permit # 2013-334-NA-2013-76).

Human sensitivity scores

We ranked each species as having a strong (>50%) or moderate decline (<50%), or having increased (more individuals observed per kilometer in 2014 than in 2009) inside the Wami-Mbiki core area based on the change in the number of individuals observed per kilometer of each species between 2009 and 2014. To assess the relative abundance of each species, we ranked the 22 species present during the 2014 survey based on the percentage of transects with either direct or indirect observations. We classified species as rare if they were observed on <25% of transects, uncommon between 25 and 50% of transects, and common >50% of transects.

Following the classification of transect data, we ranked each species as having a strong (>50%) or moderate decline (<50%) outside of Wami-Mbiki Wildlife Management Area based on the change in the number of Wami-Mbiki Society villages (24 in total) that reported presence of each species between 2009 and 2014. Subsequently, we ranked species as rare outside of the Wildlife Management Area if <25% of villages reported their presence at least once per year, as uncommon if reported if 25 and 50% of villages, and common >50% of villages reporting their presence, based on all 80 villages interviewed.

We combined the species' presence and population trend results from both the transect survey and interview data to create a human sensitivity score for each species. First, we assigned ordinal values to species' population trends inside and outside Wami-Mbiki Wildlife Management Area (3 for species that were present on transects in 2009 but absent in 2014, 2 for species with strong declines, 1 for species with moderate declines, and 0 for species that increased). We then assigned ordinal values to how common species were inside and outside Wami-Mbiki Management Area based on presence data (3 for absent species, 2 for rare, 1 for uncommon, and 0 for common). We summed all values for species across trend and presence data (thus equally weighting each method of data collection and data type) and divided this value by the maximum possible value for each species (thus giving an average human "sensitivity score" across the two survey methods and data types). The resulting human sensitivity scores varied from 0 to 1, and arbitrarily we classified species as *species in danger* if they had a human sensitivity score greater than 0.75, *human avoiders* for scores between 0.75 and 0.5, *human adapters* for scores between 0.5 and 0.25, and *human exploiters* for species with scores less than 0.25.

Results

Species sensitivities: Wildlife transects

Thirteen mammal species were directly observed on transects (33.5% of species presence data), with an additional 9 species noted by indirect observation (presence determined via dung or footprints; 66.5% of species presence data) (Table 2, Column 2). Six of the 17 species observed directly during the 2009 survey by TAWIRI were not observed in our survey (buffalo, eland, elephant, giraffe, lion and sable), but all were present based on indirect observations. Six species (hartebeest, impala, reedbuck, warthog, waterbuck and plains zebra) showed strong declines (>50% decline in observations of individuals) between 2009 and 2014. Baboon, bushbuck and duiker suffered moderate declines (25-50%), while both greater kudu and hare increased between surveys (Table 2, Column 3).

In the reserve, we observed high numbers of pastoralists and farmers (209 people) and their livestock throughout the core area; we noted the presence of livestock and/or people on all 31 transects. Cattle increased substantially between 2009 (0.39 cows observed per kilometer of transect walked) and 2014 (19.10 cows/km) by 4797%. Goats and sheep were not observed on transects in 2009, but in 2014 were the second most numerous mammal group encountered after cattle. Observations of livestock outnumbered wild animals by a ratio of nearly 28 to 1.

Species sensitivities: Interviews

Twenty-four mammal species were reported as having presence around the villages surrounding Wami-Mbiki Wildlife Management Area (Table 2, Column 5). All mammal species reported as present in 2009 were reported again in the 2014 interviews.

Species sensitivities: Classifications

Four LAMs (African wild dog, black rhinoceros, cheetah, and common eland) have combined human sensitivity scores >0.75, and are likely in the greatest danger of local extirpation in the face of human impacts (Table 2). As such, we classify them as LAM *species in danger*.

We classify 10 LAMs (African buffalo, Angola black-and-white colobus, common hippopotamus, common waterbuck, common wildebeest, giraffe, lion, plains zebra, sable antelope, and spotted hyena) as *human avoiders* (combined observed human sensitivity scores between 0.75 and 0.50) (Table 2).

We found nine LAMs (blue monkey, Bohr reedbuck, bushpig, common warthog, impala, leopard, Lichtenstein's hartebeest, savanna elephant and vervet monkey) were *human adapters* (combined observed human sensitivity scores 0.25-0.50) (Table 2).

Finally, we found five species of LAMs (bushbuck, bush duiker, greater kudu, hare, and yellow baboon) were being relatively unaffected by human presence (combined observed human sensitivity scores <0.25) (Table 2), and as such are likely *human exploiters*.

Sensitivities and ecological traits

To assess the validity of our human sensitivity scores, we regressed our observed values on the species-specific ecological traits; log-transformed body mass ($R^2 = 0.147$; $p = 0.044$) (Fig 4a), log-transformed home range size ($R^2 = 0.258$; $p = 0.006$) (Fig. 4b), niche breadth ($R^2 = 0.058$; $p = 0.219$) and trophic level ($R^2 = 0.075$; $p = 0.160$). We also regressed our observed human sensitivity scores on the predicted susceptibility to humans and found the relationship highly significant ($R^2 = 0.493$; $p = 0.00003$) (Fig. 4c). Body mass, home range size and predicted human susceptibility scores were thus all significantly positively correlated with observed human sensitivity in this area of Tanzania.

Discussion

In general there was extremely strong congruence between predicted susceptibility scores and our field data on sensitivities (Figure 4c). This shows that our methods of data collection based on transects and interviews combined together in a coarse fashion have considerable external validity.

Matching predicted human susceptibility to observed human sensitivity

Figure 4c shows that all LAM *species in danger* and *human avoiders* had high predicted human susceptibility scores (9 or 10), except for Angola black-and-white colobus (6), common wildebeest (6) and spotted hyena (8) (see also Table 1). Angola black-and-white colobus were noted as uncommon on village land and were absent from transects even though they are not very susceptible a priori. This might reflect the scarcity of the dense, mature forest habitat that they require which is patchily distributed in and around Wami-Mbiki Wildlife Management Area, rather than a greater-than-predicted susceptibility to humans. Spotted hyena were more sensitive based on our field data than would be predicted from their susceptibility; this species is rare in the Wildlife Management Area and ranked as uncommon and strongly declining on village land. While spotted hyenas are often considered adaptable to human presence, even living on the outskirts of urban areas (Abay et al. 2011; Foley et al. 2014), their declines and rarity in the study area may reflect poisoning. Indeed, all large carnivores (African wild dog, cheetah, leopard, lion, and spotted hyena) were either absent or rare within the Wildlife Management Area (and never directly observed), and absent or declining outside the reserve according to village interviews. Wildebeest were not historically found within the Wildlife Management Area, but are native to Mikumi National Park and Selous Game Reserve, and have been introduced to Saadani National Park. We found that they were rare outside of the reserve (<25% of villages reporting presence). Given their historic rarity in the study area, and highly migratory nature, it is perhaps unsurprising that sensitivity and susceptibility ranks are mismatched for this species.

Conversely, our *a priori* human susceptibility scores over predicted human sensitivity for two species; greater kudu and yellow baboon (Figure 4c). Greater kudu were noted in greater abundance in our study area than would be predicted by their relatively high human susceptibility. This species is common in the Wildlife Management Area based on indirect observations (tied for the highest percentage of transect presence) and were one of only two species to have increased in relative abundance between 2009 and 2014. Outside of the reserve, greater kudu were noted during interviews as being uncommon (45% of villages reporting presence), however. This suggests that on the ground greater kudu may be far more adaptable to humans than their size, home range or niche breadth would actually predict. Although commonly hunted for bushmeat, greater kudu may persist due to their secretive nature and ability to become nocturnal in areas with human disturbance, so long as sufficient cover is present (Foley et al. 2014; Hoffmann 2016). Based on home range size, niche breadth and trophic level, it was also predicted that yellow baboon would be moderately susceptibility to humans, however this species is common both inside and outside of the Wildlife Management Area and we classify yellow baboons as *human exploiters*. This is likely due to this species' ability to use agricultural land for foraging, although crop-raiding may result in their being persecuted for pest control (Foley et al. 2014).

Drivers of wildlife decline

Wildlife decline throughout our study area correlates with regional metrics of increasing human impact over the study period. Human population in the seven districts where we conducted our interviews (Bagamoyo, Handeni, Handeni Town, Kilindi, Kilosa, Morogoro, and Morogoro Urban) increased by 30.0% (from 1,861,185 to 2,419,253 people) between 2002 and 2012 (NBS Tanzania 2013). During the approximate study period (2010-2015), in the study area alone (defined by the extent of the interviewed villages plus 0.05 decimal degrees), human population is estimated to have increased by 17.7% (CIESIN 2017). We found that in the Wami-Mbiki core area, cattle increased by a staggering 4797% between 2009 (0.39 cows/km) and 2014 (19.10 cows/km). Goats and sheep were not observed on transects in 2009, but in 2014 were the second most numerous mammal group encountered after cattle.

These human and livestock population increases correspond with measures of habitat degradation. Between 2009 and 2014, our study area lost 99,629 hectares of tree cover (Hansen et al. 2013) with greater than 20% canopy density (Open Woodland to Closed Forest; Grunblatt et al. 1989). This represents a 4.3% loss of tree cover (0.6% yearly deforestation rate) during our study period. All told, over a third (35.0%) of the study area has been converted to anthropogenic land cover (Jacobson et al. 2015). Furthermore, we expect anthropogenic impacts to rise substantially as the human population of our study area is expected to increase by 213.5% by 2050 and 347.7% by 2100 (Jones & O'Neill 2016; Jones & O'Neill 2017).

Other factors, such as long-term climate change, short-term climatic variation and drought can also play a role in wildlife declines. For example, in Maasai Mara National Reserve, Kenya all large herbivores species but zebra decreased in abundance during drought years and increased in wet years, suggesting climate-related impacts on wildlife numbers (Ogutu et al. 2009). Therefore, it is likely that back-to-back failure of rains in East Africa in 2010 and 2011 had long-lasting impacts on wildlife populations in Wami-Mbiki Wildlife Management Area and the surrounding landscape (Funk 2012; Lyon & DeWitt 2012). These climatic effects, coupled with increases in human pressure would be expected to reduce wildlife populations in our study area, and teasing apart the species-by-species impacts of each driver of wildlife decline is vital to direct conservation decisions. The impacts of long-term climate change on wildlife in Tanzania are more challenging to predict. While the median predictions of precipitation change range between +7 and +14% by the 2090s (median projected change under the B1, A1B and A2 emission scenarios), temperature is expected to increase between 2.1 and 3.9°C, thereby potentially negating increased rainfall with increased drying (McSweeney et al. 2010).

Conclusion

Of the 28 species of larger mammals studied, our new data enable us to classify four species as *LAM species in danger* (i.e., are the species most likely to be extirpated first following anthropogenic impacts), 10 species as *LAM human avoiders* (i.e., respond poorly to human presence), nine as *LAM human adapters* (i.e., potentially able to persist in the face of human pressure, but not without negative impacts), and five as *LAM human exploiters* (i.e., highly adaptable to anthropogenic pressure). Critically, our measures combine easy-to-conduct transect data with interview data, and evaluate temporal changes to reach conclusions about human sensitivities, and can be applied in other regions where few studies have explicitly examined wildlife declines outside protected areas.

In the context of anthropogenic pressure within and around protected areas in African savanna ecosystems a number of species - cheetah, black-and-white colobus, buffalo, eland, giraffe, hippopotamus, spotted hyena, lion, rhinoceros, sable, waterbuck, wild dog, wildebeest, and plains zebra - can each potentially function as focal species (*sensu* Lambeck 1997) to direct conservation action. Actually, many of these species are already the target of conservation efforts either because they are globally threatened with extinction (e.g., black rhinoceros [Emslie 2012] and wild dog [Woodroffe & Silero-Zubiri 2012]) or their range and/or numbers are declining (e.g., cheetah [Belbachir et al. 2015; Durant et al. 2017] and lion [Riggio et al. 2013; Bauer et al. 2015]). Others are conservation flagship species due to their charisma. For example, the members of the “Big 5”, including buffalo, lion and rhinoceros, are the classic flagship species of African savannas (Caro & Riggio 2013), while the expanded “Safari 8” species, including cheetah, giraffe, hippopotamus, hyena, wildebeest and zebra, draw additional conservation support as the focus of ecotourism in these ecosystems (Skibins et al. 2016). Furthermore black-and-white colobus have been suggested as a flagship species for coastal forest conservation in Kenya (Anderson et al. 2007) and may serve to draw conservation attention to the East African Coastal Forests biodiversity hotspot in Tanzania as well (Meyers et al. 2000; Mittermeier et al. 2011). Our findings show that over and above these species acting as conservation flagships, they also act as focal species (*sensu* Lambeck 1997) due to their heightened sensitivity to human disturbance. This now enables conservation scientists and wildlife managers to use *large African mammal human avoiders* as African focal species for conservation planning and targeted conservation efforts.

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Figure Captions

Figure 1: Wami-Mbiki Wildlife Management Area in eastern Tanzania. Inset shows the extent of the region in Tanzania. Circles show the location of all 80 interviewed villages.

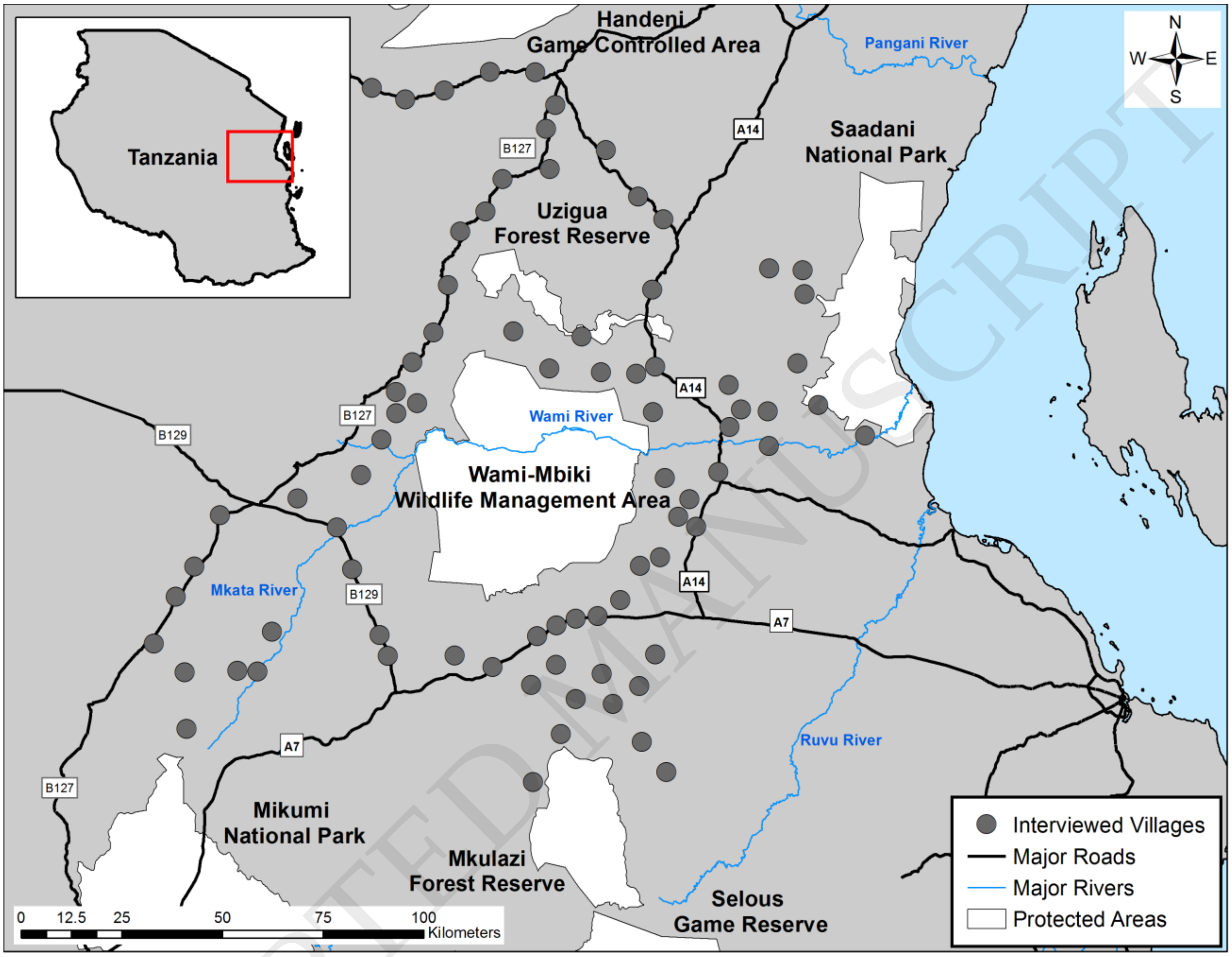

Figure 2: Locations (black triangles) of the 31 12-km transects walked in Wami-Mbiki. The large black dot shows the position of the game scout camp (Mkongo). Dotted lines indicate the locations of driving tracks within the core area.

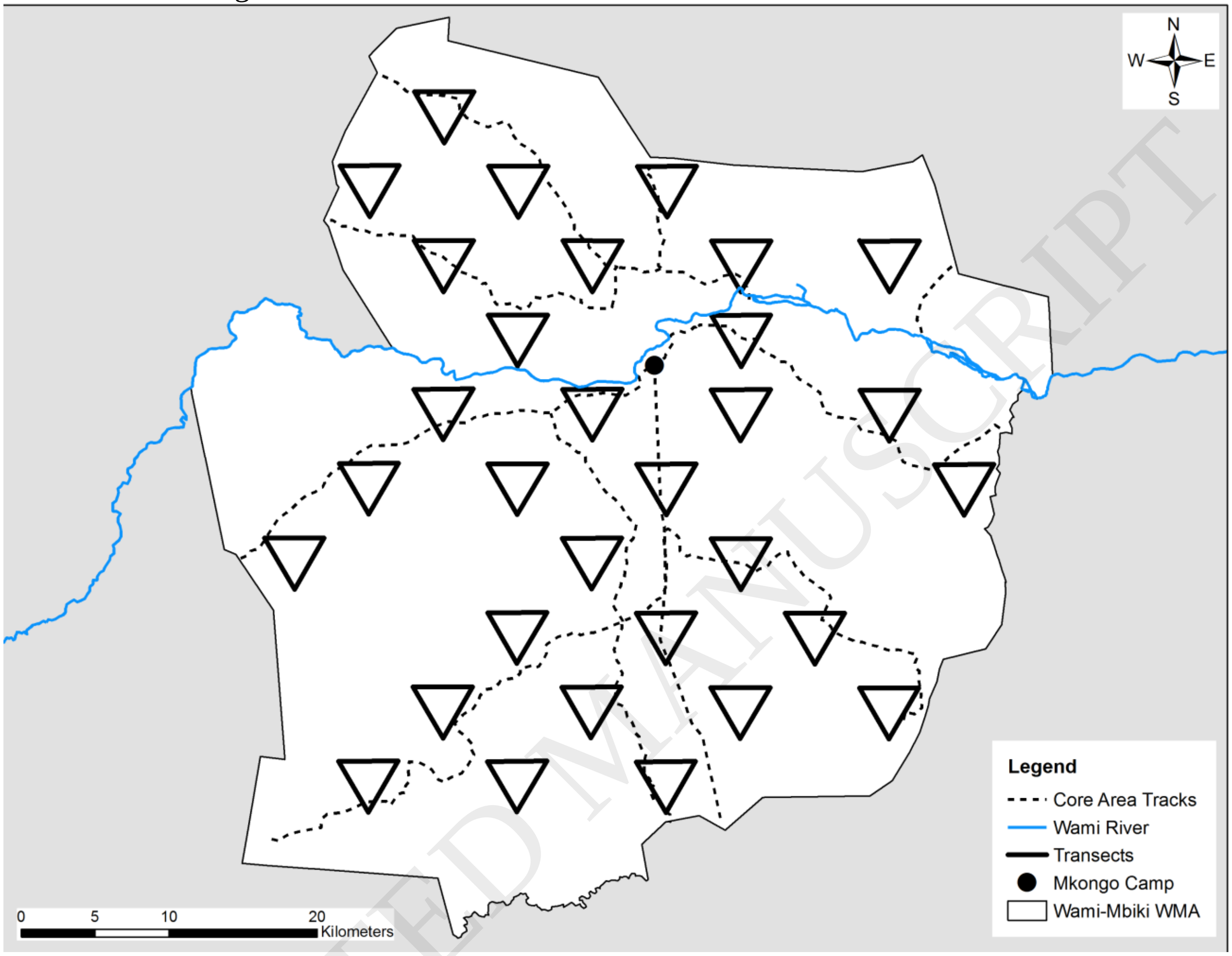

Figure 3: Large mammal rarefaction curves for the 2009 and 2014 transect surveys within Wami-Mbiki Wildlife Management Area.

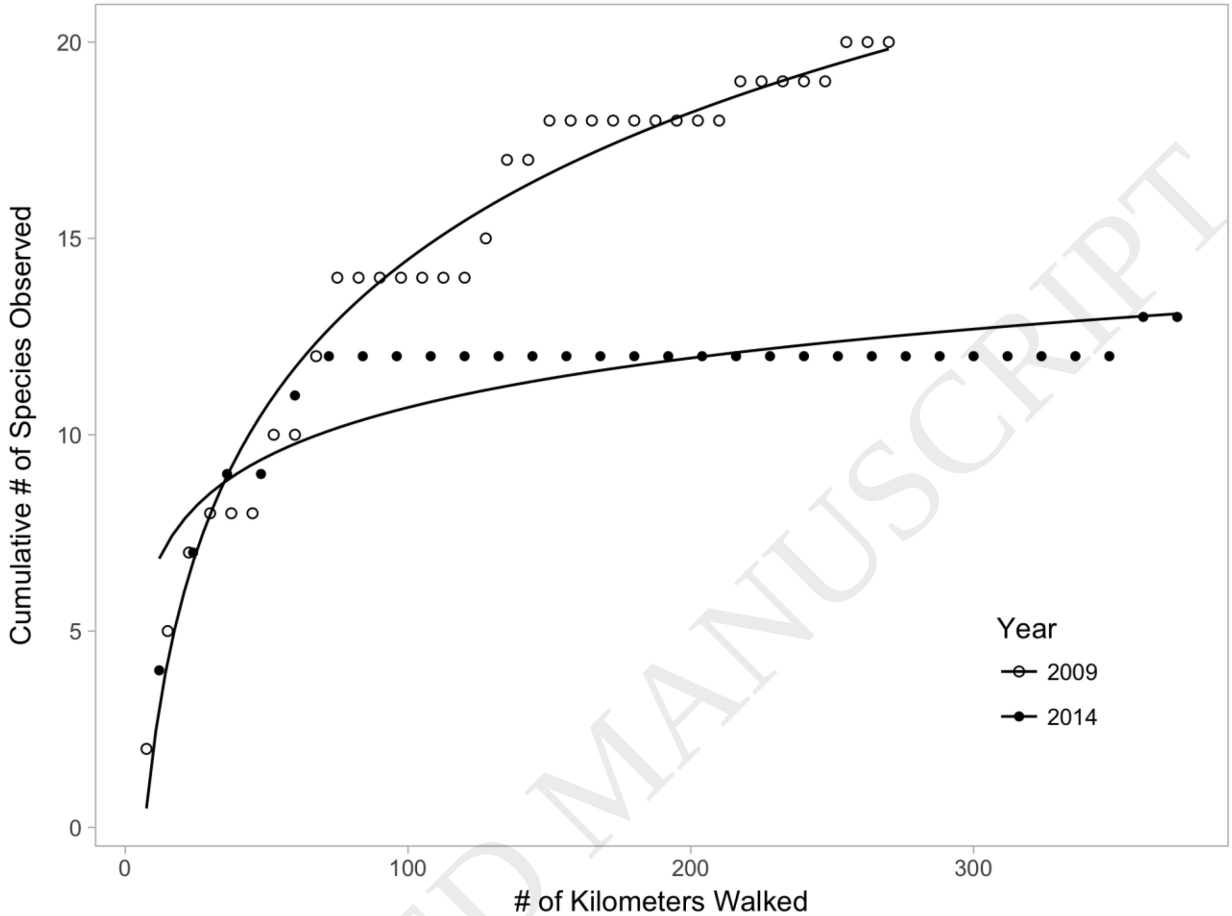

Figure 4a: Relationship between log body mass and human sensitivity score.

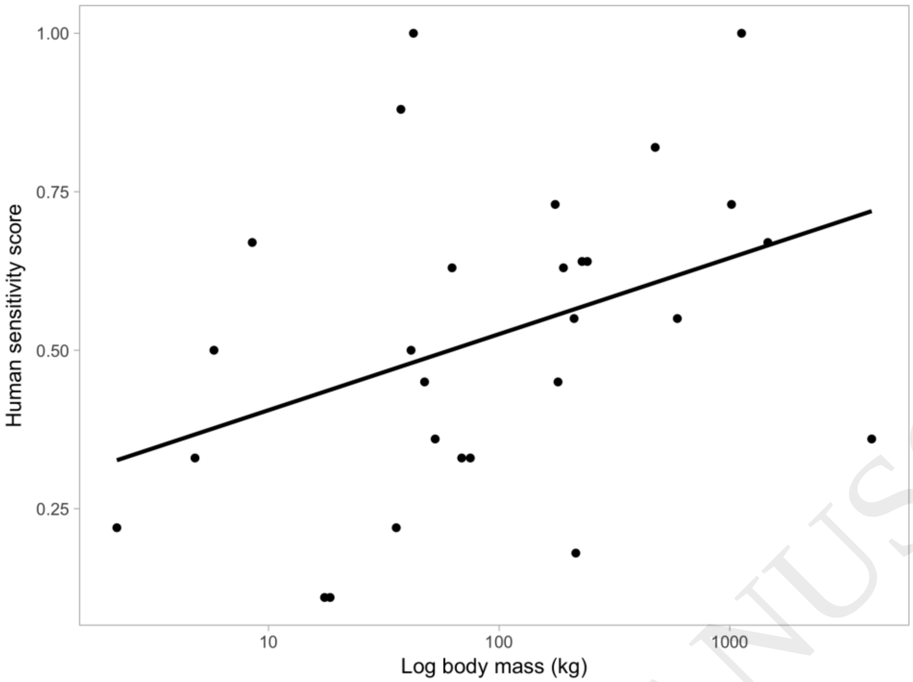

Figure 4b: Relationship between log home range size and human sensitivity score.

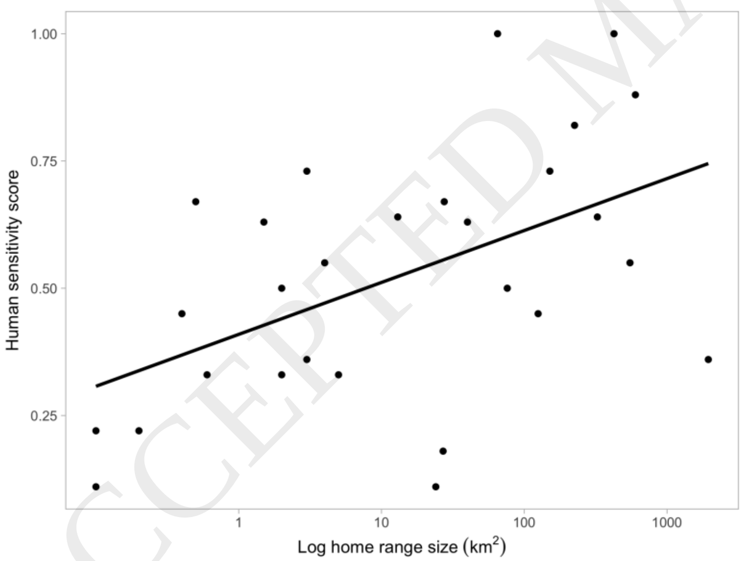

Figure 4c: Relationship between predicted human susceptibility and human sensitivity score. Horizontal dotted lines show the susceptibility classification breaks for large African mammal human exploiters (1; <0.25), human adapters (2; 0.25-0.50), human avoiders (3; 0.50-0.75), and species in danger (4; >0.75). Predicted susceptibility to humans for Angola black-and-white colobus, common wildebeest, greater kudu, spotted hyena and yellow baboon do not match our observed human sensitivity scores and are discussed in the text.

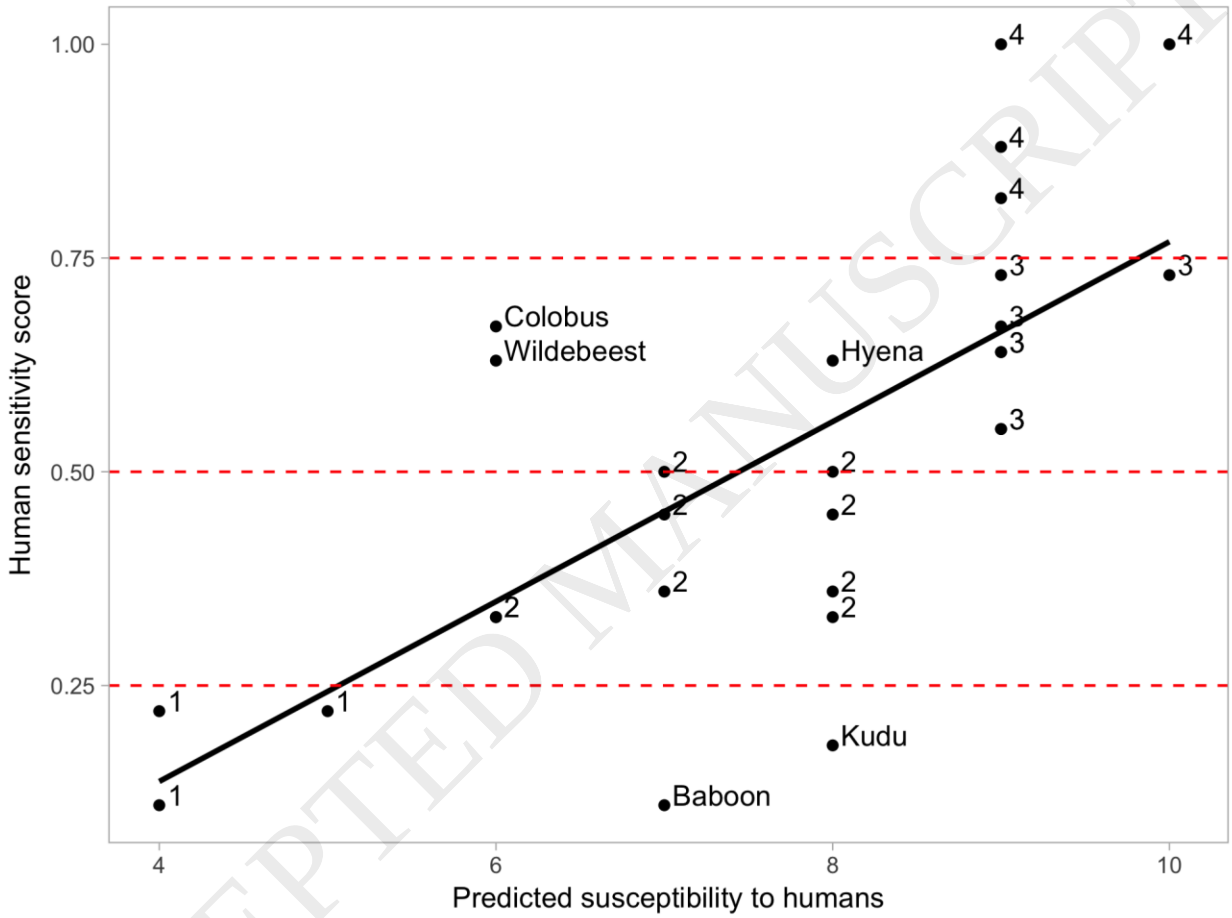

Table 1: Predicted susceptibility to humans of larger savannah mammal species.

Species [Body Mass; Home Range Size][a]	Scientific Name	Body Size Rank	Home Range Rank	Niche Breadth	Trophic Level	Predicted Susceptibility to Humans
Cheetah [43 kg; 425 km^2]	*Acinonyx jubatus*	2	3	2	3	10
Lion [180 kg; 125 km^2]	*Panthera leo*	2	3	2	3	10
African buffalo [620 kg; 550 km^2]	*Syncerus caffer*	3	3	2	1	9
African wild dog [38 kg; 600 km^2]	*Lycaon pictus*	1	3	2	3	9
Black rhinoceros [1125 kg; 65 km^2]	*Diceros bicornis*	3	3	2	1	9
Common eland [475 kg; 225 km^2]	*Tragelaphus oryx*	3	3	2	1	9
Common hippopotamus [1500 kg; 27.5 km^2]	*Hippopotamus amphibius*	3	2	3	1	9
Common waterbuck [228 kg; 4 km^2]	*Kobus ellipsiprymnus*	3	2	3	1	9
Giraffe [1050 kg; 151 km^2]	*Giraffa camelopardalis*	3	3	2	1	9
Plains zebra [248 kg; 325 km^2]	*Equus quagga*	3	3	2	1	9
Sable antelope [235 kg; 13 km^2]	*Hippotragus niger*	3	2	3	1	9
Bushpig [80 kg; 5 km^2]	*Potamochoerus larvatus*	2	2	2	2	8
Greater kudu [230 kg; 27 km^2]	*Tragelaphus strepsiceros*	3	2	2	1	8
Leopard [45 kg; 76 km^2]	*Panthera pardus*	1	3	1	3	8
Lichtenstein's hartebeest [180 kg; 3 km^2]	*Alcelaphus lichtensteinii*	2	2	3	1	8
Savanna elephant [4250 kg; 1945 km^2]	*Loxodonta africana*	3	3	1	1	8
Spotted hyena [63 kg; 40 km^2]	*Crocuta crocuta*	2	2	1	3	8
Blue monkey [6 kg; 2 km^2]	*Cercopithecus mitis*	1	1	3	2	7
Bohr reedbuck [50 kg; 0.4 km^2]	*Redunca redunca*	2	1	3	1	7
Impala [53 kg; 3 km^2]	*Aepyceros melampus*	2	2	2	1	7
Yellow baboon [19 kg; 24 km^2]	*Papio cynocephalus*	1	2	2	2	7
Angola black-and-white colobus [9 kg; 0.5 km^2]	*Colobus angolensis*	1	1	3	1	6
Common warthog [73 kg; 2 km^2]	*Phacochoerus africanus*	2	1	2	1	6
Common wildebeest [190 kg; 1.5 km^2]	*Connochaetes taurinus*	2	1	2	1	6
Vervet monkey [5 kg; 0.6 km^2]	*Chlorocebus pygerythrus*	1	1	2	2	6
Bushbuck [40 kg; 0.2 km^2]	*Tragelaphus scriptus*	1	1	2	1	5
Bush duiker [18 kg; 0.1 km2]	*Sylvicapra grimmia*	1	1	1	1	4

Hare [2 kg; 0.1 km2]	*Lepus sp.*	1	1	1	1	4

[a]Average species weight and home ranges taken from Foley et al. 2014 and Kingdon et al. 2013.

Table 2: Species presence and population trends in and around Wami-Mbiki Wildlife Management Area and corresponding observed human sensitivity scores. N/A refers to species not recorded on transects or interviews in 2009. For trend data, strong declines indicate a >50% decline, moderate decline indicates <50% decline, and not observed means this species was observed on a transect in 2009, but not recorded on a transect in 2014. For presence data, common species are reported in >50% of villages or transects, uncommon between 25 and 50%, and rare in <25% of villages or transects. *Cheetahs were mentioned in several village interviews, but we suspect that this is due to misidentification as there was no observational evidence of the species in the study area. #These species were only noted on transects via indirect observation (presence determined via dung or footprints).

Species	Transects in Wami-Mbiki Wildlife Management Area with Species' Indirect or Direct Observation in 2014	Species' population trend between 2009 and 2014 in Wami-Mbiki Wildlife Management Area	Observed Human Sensitivity Scores (Wami-Mbiki Wildlife Management Area)	Villages Reporting Species' Presence in 2014	Trend in % of Wami-Mbiki Society Villages Reporting Species' Presence between 2009 and 2014	Observed Human Sensitivity Scores (Villages)	Observed Human Sensitivity Scores (Combined)
Large African Mammal Species in Danger							
Black rhinoceros	Absent	N/A	1.00	Absent	N/A	1.00	1.00
Cheetah	Absent	N/A	1.00	Absent	N/A*	1.00	1.00
African wild dog	Absent	N/A	1.00	Rare	Strong decline	0.80	0.88
Common eland	Rare#	Not observed	0.83	Rare	Strong decline	0.80	0.82
Large African Mammal Human Avoiders							
Giraffe	Rare#	Not observed	0.83	Rare	Moderate decline	0.60	0.73
Lion	Absent	Not observed	1.00	Uncommon	Moderate decline	0.40	0.73
Common hippopotamus	Rare	N/A	0.67	Rare	N/A	0.67	0.67
Angola black-and-white colobus	Absent	N/A	1.00	Uncommon	N/A	0.33	0.67
Plains zebra	Rare	Strong decline	0.67	Rare	Moderate decline	0.60	0.64
Sable antelope	Rare#	Not observed	0.83	Uncommon	Moderate decline	0.40	0.64
Common wildebeest	Absent	N/A	1.00	Rare	No change	0.40	0.63
Spotted hyena	Rare#	N/A	0.67	Uncommon	Strong decline	0.60	0.63
African buffalo	Uncommon#	Not observed	0.67	Uncommon	Moderate decline	0.40	0.55
Common waterbuck	Rare	Strong decline	0.67	Uncommon	Moderate decline	0.40	0.55
Large African Mammal Human Adapters							
Blue monkey	Rare#	N/A	0.67	Uncommon	N/A	0.33	0.50

Leopard	Rare#	N/A	0.67	Uncommon	Moderate decline	0.40	0.50
Lichtenstein's hartebeest	Uncommon	Strong decline	0.50	Uncommon	Moderate decline	0.40	0.45
Bohr reedbuck	Uncommon	Strong decline	0.50	Uncommon	Moderate decline	0.40	0.45
Savanna elephant	Common#	Not observed	0.50	Common	Moderate decline	0.20	0.36
Impala	Common	Strong decline	0.33	Uncommon	Moderate decline	0.40	0.36
Bushpig	Rare#	N/A	0.67	Common	N/A	0.00	0.33
Common warthog	Uncommon	Strong decline	0.50	Common	N/A	0.00	0.33
Vervet monkey	Rare	N/A	0.67	Common	N/A	0.00	0.33
Large African Mammal Human Exploiters							
Bushbuck	Uncommon	Moderate decline	0.33	Common	N/A	0.00	0.22
Hare	Uncommon	Increase	0.17	Uncommon	N/A	0.33	0.22
Greater kudu	Common	Increase	0.00	Uncommon	Moderate decline	0.40	0.18
Bush duiker	Common	Moderate decline	0.17	Common	N/A	0.00	0.11
Yellow baboon	Common	Moderate decline	0.17	Common	N/A	0.00	0.11