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Does illegal hunting affect density and behaviour of African grassland birds? A case study on ostrich (*Struthio camelus*)

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Abstract Widespread bushmeat hunting represents one of the major threats to many mammals and birds in Africa. We studied the influence of illegal bushmeat hunting on large grassland birds in the Serengeti National Park (SNP) and adjoining protected areas, by using the ostrich (*Struthio camelus*) as a case study. First, we documented illegal hunting of both small and large birds by using a questionnaire in the villages on the western and eastern side of the SNP. Second, we studied the effect of illegal hunting on density by driving 4,659 km of transects inside SNP and on the adjacent protected areas, where the data were analysed by DISTANCE sampling. Last, we used flight initiation distance (FID, i.e. the distance between an approaching predator (human) and prey when flight is started), to assess possible impacts on behaviour from illegal hunting. We found that people from the western side of the SNP admitted to hunting both small and large grassland birds, and collect ostrich feathers and eggs. Although the Maasai also hunted small birds, only ostrich feathers and eggs of the large grassland birds were used. Surprisingly, we found no significant differences in densities between the SNP and adjoining partially protected areas, but ostriches had longer FID to an approaching human outside the SNP. Currently illegal hunting does not appear to affect the ostrich population, but given the extensive use of birds for consumption more awareness educational programs accompanied by provision of agricultural incentives within the protected areas are needed.

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Introduction

The human population in Africa is growing rapidly and the pressure for resources is increasing both inside and outside protected areas. Although protected areas are recognised as a key element in conservation, studies show that partially protected areas (IUCN category $\leq$ IV) do not protect biodiversity as well as strictly protected areas (Caro et al. 1998; Caro 1999; Pelkey et al. 2000; Setsaas et al. 2007). Nevertheless, partially protected areas compose a significant part of the protected area network in Southern Africa (WRI 2005). The lack of adequate law enforcement within these areas that can control and regulate human activity (i.e. livestock grazing, illegal bushmeat hunting, firewood extraction) is suggested as an important factor in the observed decline in both mammal populations and vegetation cover (Caro et al. 2000; Pelkey et al. 2000).

Human activity is also affecting bird populations adversely through hunting, or may indirectly have implications for bird survival and reproduction through changes in their habitat (e.g. deforestation and fragmentation) (Fjeldsa 1999; Lawes et al. 2006; Manu et al. 2007) or through forcing birds to use sub-optimal areas because of disturbance effects (Rodger and Smith 1997; Herremanns 1998; Blumstein 2006). For instance, Sinclair et al. (2002) found that non-protected areas under cultivation support many fewer bird species compared to the native vegetation inside a strict protected area. Overgrazing by livestock has also negative consequences for some grassland bird species (Herremanns 1998; Thiollay 2006a). Similarly, Thiollay (2006a) documented dramatic declines in large birds in non-protected areas in Burkina Faso, but also noted a decline in bird populations within protected areas close to human settlements. Illegal hunting was suggested to be the main factor, where hunters increasingly targeted large game birds, such as guinea fowls (*Numida meleagris*) and bustards (*Ardeotis* spp.), as other mammalian prey disappeared. This situation appears to be symptomatic for large birds in the rest of North and West Africa, where for example, the ostrich (*Struthio camelus*), which was once widespread, is now extirpated west of Chad (Thiollay 2006b) and the northern side of the Sahara (Bertram 1992), and is threatened with extirpation in the western Sahara (Bertram 1992; Ostrowski et al. 2001). Grassland bird species appear to be under less pressure in Southern Africa but few studies have examined possible effects of human activities on bird populations within protected areas in the region (Herremanns 1998; Hugo and van Rensburg 2008).

The use of behaviour has been proposed as an indicator for assessing disturbance effects of human activity (Caro et al. 1998). Flight initiation distance (FID, i.e. the distance between an approaching human and prey when flight commences) is the most commonly used parameter to assess the effect of human disturbance (reviewed in Stankowich and Blumstein 2005), and has also been used to investigate the influence of hunting (de Boer et al. 2004; Matson et al. 2005; Setsaas et al. 2007; Thiel et al. 2007). Modelling shows tremendous reductions in the number of food items captured following disturbance, which indicates that a change in shyness might be of conservation significance (Blumstein et al. 2005).

The Serengeti National Park (SNP) in northern-Tanzania is surrounded by several partially protected areas, which have experienced high levels of illegal bushmeat hunting (Dublin et al. 1990; Campbell and Hofer 1995; Hofer et al. 1996). Illegal bushmeat hunting

mainly originates from the villages to the west of the SNP, since the pastoralist Maasai living to the east mainly live on livestock and do not traditionally eat wild animal meat (Campbell and Hofer 1995). The main motivation behind hunting is to increase food supply and cash income (Loibooki et al. 2002; Holmern et al. 2002; Kaltenborn et al. 2005). Illegal bushmeat hunting is primarily done with snares and targets large herbivores, but hunting of birds by the people living around the Serengeti remains largely unexplored.

The objective of this study was to establish the extent to which local people around the SNP utilise three typical large grassland birds, ostriches, kori bustard (*Ardeotis kori*) and guinea fowl, by comparing tribes with long hunting traditions (e.g. Ikoma and Kurya) on the western side of the national park with the largely pastoral Maasai living on the eastern side. Furthermore, we examined in more detail how successful the partial protected areas were in conserving ostrich populations, in terms of densities and flight behaviour as compared to a strictly protected area (SNP).

Methods

Study area

The study was conducted in the SNP (14,763 km^2) and adjacent partially protected areas: Grumeti Game Reserve (ca. 400 km^2), Ikorongo Game Reserve (ca. 600 km^2) and Ikoma Open Area (600 km^2), in Northern Tanzania (Fig. 1). In SNP only photographic tourism is allowed and no human settlements or consumptive activities are permitted. In the Grumeti and Ikorongo Game Reserves trophy hunting and photographic tourism are allowed, as well as game cropping, but no other consumptive activities are permitted. The Ikoma Open Area also allows the same activities as within the Game Reserves, but in addition permits human settlement and limited human activities such as livestock keeping, legal resident hunting, farming, small scale mining and firewood collection. Licensed tourist and legal resident hunting is conducted from vehicles in the hunting season (1st July–31st December). The study area is composed of highland savannah with mainly thorn woodland trees (with species of *Acacia, Comiphora, Ficus, Combretum* and *Podocarpus*) and extensive grass plains (Herlocker 1976).

The Ngorongoro Conservation Area (NCA) (8,300 km^2) lies east of the SNP and is contiguous with the southern Serengeti plains. It was established to both protect wildlife and allow the Maasai tribe to continue with their traditional pastoral activities, after being expelled from their traditional areas within the SNP. Currently the NCA allows photographic tourism, human settlements (i.e. the Maasai), livestock grazing and small scale cultivation that have increased in the past decade. The human population within NCA in 2002 was approximately 60,000 and has been increasing at a rate of 3.5% per annum (Boone et al. 2006).

Study species

We specifically focused on three easily identifiable and characteristic grassland bird species: ostrich ($\sim$145 kg), kori bustard ($\sim$13 kg males, $\sim$8 kg females) and guinea fowl ($\sim$1.3 kg). These three species are ground nesters and are found in a variety of open habitat types in the Serengeti ecosystem. Ostriches and guinea fowl are found throughout the ecosystem, whereas kori bustards are found mostly on the grasslands and lightly

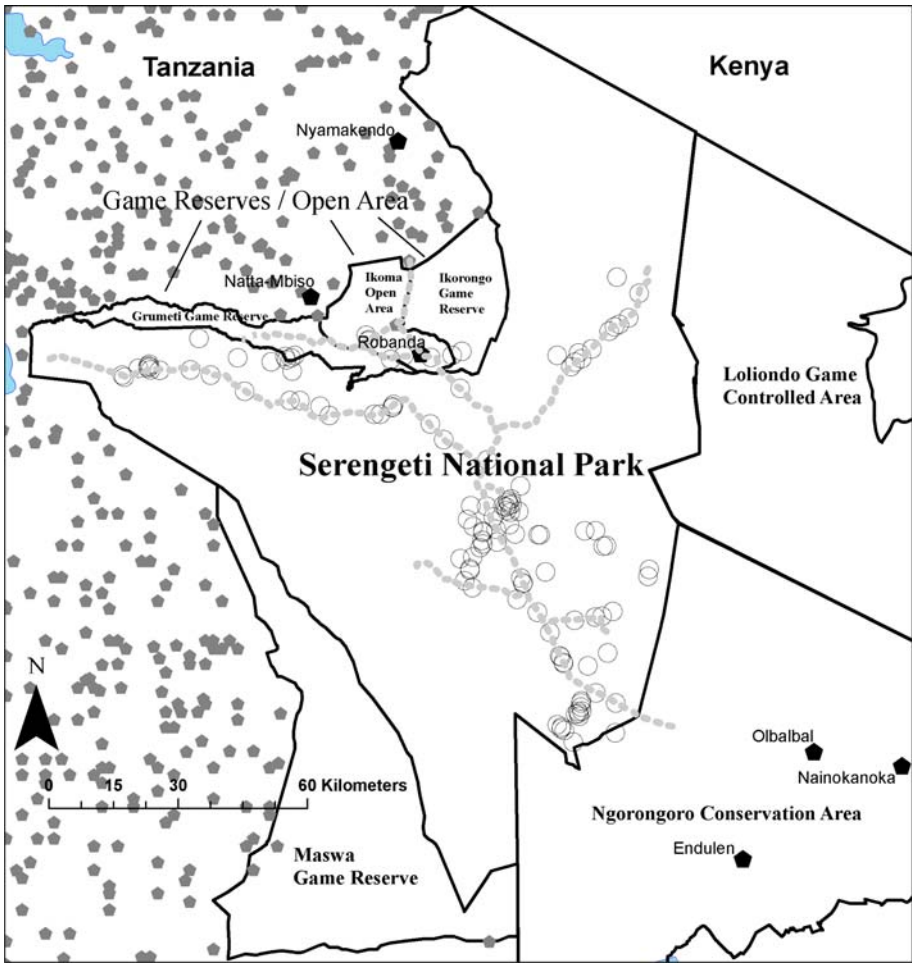


Fig. 1 Map of the protected areas in the Serengeti ecosystem. Thick lines denote the protected areas. The western Serengeti shows all villages as grey pentagons and the study villages used for the questionnaire survey as black pentagons. In the Ngorongoro Conservation Area only the three study villages are shown as black pentagons. In addition, the positions of transects are shown as short grey lines, whereas circles show the locations of FID experiments

wooded savannas (Stevenson and Fanshawe 2002). Both kori bustard and guinea fowl can fly, whereas ostriches are flightless and rely on running to escape predators.

Questionnaire data

Data on illegal hunting of birds was collected through questionnaires in six villages located in western and eastern SNP from June to July 2006. Our survey encompassed a total of 115 questionnaires, that were randomly selected (every tenth household) from household lists in each village. The villages included Robanda, Natta Mbiso and Nyamakendo on the western side of the SNP, where the respondents came from the Ikoma, Natta and Kurya tribes, respectively. On the eastern side of SNP the villages included Olbalbal, Endulen and

Nainokanoka (all located in the NCA) (Fig. 1) and all respondents here where Maasai. The questionnaires focused on: (i) methods of hunting, (ii) number of birds hunted per week, (iii) the bird preferred and (iv) uses of bird products focusing on guinea fowl, kori bustard and ostrich. The hunting of small birds was mainly a juvenile activity, therefore respondents (household heads or grown-ups) were asked to estimate the total number of birds killed, as well as the species.

Transects

Data were collected from April 2004 to October 2005 (19 months), where we used the line transect based distance sampling method (Buckland et al. 2001) to estimate ostrich density (individuals/km^2). The method is based on records of the distance from the line to each object detected when the observer travels along the line (we scanned upto 1,000 m). The occurrence of animals was observed by two observers covering a sector of 180° to the right and left sides of the transect, respectively. Ostriches were detected from a vehicle (Land rover pickup) travelling at 15–20 km/h. Upon detection a rangefinder (i.e. Leica Geovid 7 × 42 BDA) was used to determine distance and angle to the transect. The perpendicular distance to the transect was calculated by applying the following recorded measurements: (i) measurements of the distance from the observer to single ostriches or to the centre of clusters and (ii) corresponding measurements of the angles between the transect line and the lines between the observer and detected objects. This information was used with the Distance software (Buckland et al. 2001) to fit detection functions that determine the density per main transect (see below). One great advantage of this approach is that we need draw no distinction, within reasonable limits, between habitats with good or poor visibility. The fitted detection function reflects both the decrease in detectability with distance and the lower proportion of animals that are potentially detectable (Buckland et al. 2001). For each sighting, we recorded the number of birds and habitat type (according to Kikula 1980; Caro 1999), but because of small sample size we pooled habitat types into two categories, closed habitat (woodlands and bushlands) and open habitat (grasslands, wooded grasslands, bushed grasslands and cultivated lands).

The transects were systematically spaced and superimposed on the existing road system in the study area (Fig. 1). This was necessary due to the ruggedness of the terrain and because cutting new tracks was not allowed. Each transect had a total length of 1 km and transects were spaced with intervals of 2 km. A total of 195 transects were recorded, sampling was conducted once a month, and altogether 4,659 km of transects were driven. We estimated density inside the SNP and in the adjacent partially protected areas outside the SNP. The few transects located within NCA were pooled together with partially protected areas on the western side of the park to increase sample sizes (Fig. 1). The seasons were categorised as wet (November–May) and dry (June–October) seasons. In order to control for possible habitat differences between the areas of comparison, we used ArcView 9.0 to calculate the area (km^2) of vegetation types within a 1 km envelope on both sides of each transect by using a land cover—land use map of the area. The results were recorded according to four categories: grasslands, bushland, woodland and urban/cultivation.

Anti-predator behaviour

Flight behaviour was recorded from August to December 2003, and January to February 2006 along roads and tracks inside and outside the SNP between 6:00 a.m and 6:00 p.m. Only birds engaged in relaxed behaviours such as feeding, resting or preening were

examined. Highly vigilant and nesting individuals were not approached. Individuals that were less than 100 m apart were considered as one group. Immediately after spotting an ostrich or group of ostriches, we stopped the vehicle and recorded group size, group composition, behaviour, habitat, alertness (individuals being alert or not before the approach) and the distance from the car to the centre individual (i.e. starting distance). Then the test person (wearing neutral coloured clothing) approached the ostrich(es) at a steady pace ($\sim$0.5 m/s). When the birds fled the test person immediately stopped and the distance to the test person was recorded. The FID was the difference between the starting distance and the distance to the test person when the bird(s) took flight. We sampled ostriches over a large area, but in order to minimise the potential problem of pseudoreplication we never re-sampled an area before at least a week had passed. However, according to Runyan and Blumstein (2004) a modest degree of pseudoreplication does not affect results in FID studies.

Statistical analyses

We used DISTANCE 5.0, release 2 (Thomas et al. 2006) to estimate densities (ostriches/km^2). Right truncations of sighting distance frequency distribution were performed by visual inspection and by applying the distance corresponding to a recommended truncation value of 0.15 of the detection function (Buckland et al. 2001). The detection function reflects both the decrease in detectability with distance and the lower proportion of animals that are potentially detectable (Buckland et al. 2001). The DISTANCE software estimates the detection probability of an animal as a function of distance. The negative exponential, global detection function with cosine expansions (Buckland et al. 2001) was chosen using Akaike's Information Criterion (AIC) corrected for small samples and chi-square goodness-of-fit tests (Sakamoto et al. 1986). We calculated ostrich densities for areas and habitat types having more than 40 observations although a sample size of minimum of 60 observations is recommended by Buckland et al. (2001). Upto 12 models were generated in each analysis, and the best model was selected basing on the lowest ΔAIC_c. The densities were considered statistically significant if the confidence interval values did not overlap (Buckland et al. 2001).

Predators do not commence approaches of prey at fixed distances, and it is not surprising that starting distance strongly influences alert distance and FID, as previous studies have shown in birds (Fernádez-Juricic and Schröeder 2003; Blumstein 2003). Thus, we incorporated starting distance as an independent variable in all our tests. We used linear-mixed models, to account for possible year effects due to sampling over two different years (the two test persons used were also nested inside the same variable), in order to explore the variables influencing FID, with year set as a random effect (Crawley 2002). The predictor variables included in the models were therefore starting distance, area (inside or outside the national park), alertness (whether or not the focal individual was alert prior to the approach), group size and group composition (male, female, mixed). However, the analysis was restricted to approaches done in open vegetation, due to low sample size. In the analysis the variables FID and starting distance were square root transformed to improve normality of residual errors. We selected the most parsimonious model from a set of appropriate models according to Akaike Information Criterion corrected for small samples (AIC_c) (Burnham and Anderson 2002). The best models were those with lowest AIC_c values, highest Akaike weights (ω_i) and $\Delta AIC_c < 2$, but the most parsimonious model was the one with lowest number of parameters among those with $\Delta AIC_c < 2$. The Akaike weight indicates the probability that the model is the best among the whole set of

candidate models. The analyses were performed using R 2.3.0 Software (R Development Core Team 2006). Data are presented as mean ± SE.

Results

Illegal hunting

Respondents volunteered no bird hunting information conducted by themselves or their households, but admitted that hunting of birds was conducted in their villages. Hunting of small birds was primarily done by juveniles (e.g. shepherds). However, the majority of the local people interviewed in both western Serengeti (98.3%, $n = 59$) and NCA (71.4%, $n = 56$) admitted that people in their villages hunted small sized birds (<1 kg, Table 1) for food, but it was more usual in the western Serengeti ($\chi^2 = 16.47$, df = 1, $P < 0.001$). The commonly hunted small birds were doves and francolins in western Serengeti and NCA, respectively (Table 1). The hunting methods were similar in both areas, where the use of birdlime (adhesive substance made from tree barks commonly of genus *Holly*, used in trapping birds) (48.9%) was most common, followed by slingshot (34.7%), dogs (12.2%) and other (i.e. stick and stones, 4.1%). The respondents estimated how many small birds were hunted on average per week, where there was no significant difference between the two areas (western Serengeti: 9.8 ± 1.3 small birds, NCA: 8.71 ± 1.7 small birds) (Mann–Whitney U test = 494.5, $Z = -0.72$, $n_1 = 46$, $n_2 = 24$, $P = 0.47$).

Hunting of large birds (>1 Kg) was done by both juveniles and adults. A wide variety of weapons were used according to respondents to hunt large grassland birds, where snares were the most common method to catch ostriches (Table 2). The hunting tribes in western Serengeti replied that all the focal grassland birds were hunted for meat, and they also collected eggs and feathers. On the other hand, the Maasai living in NCA claimed to collect only eggs and feathers from ostriches and guinea fowl, and did not use any products of kori bustards (Table 3). Respondents in western Serengeti replied that guinea fowl were the most preferred species (83%), whereas since the respondents in NCA did not hunt large grassland birds, they answered that ostrich eggs were most preferred (91%).

Nobody replied that they themselves had traded bird products, but in overall (i.e. both in western Serengeti and NCA), 33.9% of the respondents replied that people in their villages had sold ostrich products, such as eggs (price/egg: US$ 1.03 ± 0.9, $n = 23$) and meat (1–2 kg dry meat: US$ 1.4 ± 1.0, $n = 10$), and that some of the buyers were villagers (84.62%), tourists (7.69%) and hoteliers (7.69%) (no distinction was made between local and tourist hotels).

Table 1 Type of small birds hunted according to replies from respondents in households in western Serengeti and the Ngorongoro Conservation Area (NCA)

Western Serengeti	Percentage	NCA	Percentage
None	23.7	None	87.5
Doves	47.5	Francolin	7.1
Francolin	20.4	Parrot	3.6
Parrot	5.1	Weaver[a]	1.8
Weaver[a]	11.9	–	–

[a] All small colourful birds were classified as weavers by respondents

Table 2 Weapons used by illegal hunters to hunt the focal large grassland birds (Ser = western Serengeti, Ngorongoro Conservation Area = NCA)

Weapon	Ostrich		Guinea fowl		Kori bustard	
	Ser (%)	NCA (%)	Ser (%)	NCA (%)	Ser (%)	NCA (%)
None	11.7	1.8	6.7	100	–	–
Snare	47.5	–	–	–	–	–
Eggs and feathers	13.6	98.2	–	–	–	–
Spear	11.9	–	–	–	–	–
Rope	8.5	–	78	–	–	–
Bow and arrow	3.4	–	–	–	1.7	–
Gun	3.4	–	–	–	–	–
Dogs	–	–	6.7	–	–	–
Birdlime	–	–	6.7	–	–	–
Slingshot	–	–	1.7	–	–	–

Table 3 Use of bird products by households as claimed by respondents

Product	Ostrich (%)		Guinea fowl (%)		Kori bustard (%)	
	Serengeti	Ngorongoro	Serengeti	Ngorongoro	Serengeti	Ngorongoro
None	11.9	1.8	1.7	96.4	89.8	100
Eggs	76.3	94.7	89.9	1.8	–	–
Feathers	57.7	96.5	11.9	1.8	1.7	–
Meat	55.9	–	89.9	–	8.5	–
Total	201.8	193	193.4	100	100	100

Density estimates

A total of 634 ostriches were recorded, from which density estimates were obtained. The overall density (i.e. national park, NCA, game reserves and open areas combined) was (0.16 ± 0.03 ostriches/km^2) (Table 4). There were no statistical differences in ostrich density between the national park and the partially protected areas, between wet and the

Table 4 Total number of observations (with total number of ostriches in parentheses) and densities according to area (inside and outside SNP), season and habitat categories

	Description	*N*	Density ± SE (95% CI)	Goodness of fit (*P* value)
Overall density	–	207 (634)	0.16 ± 0.03 (0.11–0.22)	0.90
Area	Outside SNP	52 (137)	0.25 ± 0.09 (0.12–0.52)	0.78
	Inside SNP	155 (497)	0.15 ± 0.03 (0.10–0.21)	0.94
Season	Wet	115 (422)	0.29 ± 0.06 (0.20–0.44)	0.95
	Dry	92 (212)	0.17 ± 0.04 (0.11–0.26)	0.77
Habitat	Open	144 (450)	0.22 ± 0.04 (0.07–0.26)	0.67
	Closed	63 (184)	0.13 ± 0.05 (0.15–0.32)	0.94

Densities (per km^2) are reported as mean ± SE (95% confidence interval in parenthesis)

Table 5 Habitat types represented in the transect envelopes outside and inside the SNP

Area	Habitat types (%)			
	Grassland	Bushland	Woodland	Urban/cultivation
Outside SNP	14.3	32.6	49.1	4.0
Inside SNP	67.1	28.8	4.1	0.1

dry season or in the open habitats as compared to closed habitats. But there was a significant difference in the percentage area of each of the four vegetation types (Table 5) along the transect envelopes outside and inside the SNP ($\chi^2 = 760.6$, df = 3, $P < 0.001$).

Anti-predator behaviour

We conducted a total of 129 approaches toward ostriches. There were three models out of a total of sixteen candidate models that were considered. The three models had a $\Delta AIC_c < 2$ in the analysis of FID (Table 6). However, the first model contained three variables and was therefore not the most parsimonious. The most parsimonious model (second model) included the variables starting distance and area. Starting distance increased with FID, and FID was larger in the partially protected areas (Table 6, 7).

Discussion

Illegal bushmeat hunting

Bushmeat is an important part of the diet in most areas in Sub-Saharan Africa (Anstey 1991; Barnett 2000). The use of birds in the Serengeti ecosystem also reflects this, where

Table 6 Set of linear-mixed models with year set as a random effect explaining FID for ostriches in the Serengeti ecosystem

Model	*K*	AIC_c	ΔAIC_c	ω_i
STD + alert + area	6	437.1	0.000	0.252
STD + area	5	438.1	1.035	0.150
STD + alert	4	438.2	1.115	0.144
STD + alert + area + group size	7	439.3	2.192	0.084
STD + alert + area + group composition	8	439.5	2.363	0.077
Global model: STD + alert + area + group size + group composition	9	441.7	4.641	0.025

The models are ranked by the Akaike Information Criterion corrected for small samples (AIC_c) (K = number of parameters; ΔAIC_c = difference in AIC_c between the best model and the actual model; ω_i = Akaike weights; STD = starting distance)

Table 7 Estimate for the most parsimonious model of FID for ostriches

Coefficients	Estimate	SE	*T*	*P*-value
Intercept	−0.63	0.54	−1.16	0.248
Starting distance	0.95	0.03	30.05	<0.001
Area	0.78	0.38	2.05	0.043

the majority of the respondents replied that people in the village (both juveniles and adults) hunted birds. However, there is a slight distinction between the different tribes in regards to consumption of birds. The traditional hunting tribes in the western Serengeti, such as Ikoma, Natta and Kurya hunt and collect eggs from most birds. Of the large grassland birds, the kori bustard was the least preferred bird (Table 3), whereas almost every product from the ostrich and guinea fowl was put into use. However, for the Maasai residing within the NCA, our results indicate that it is mostly the young shepherds that hunt smaller birds. The large grassland species are mostly ignored, except ostrich eggs that are commonly collected by the Maasai. Ostrich eggs have long being prized and people have found them an invaluable food source and use empty shells as practical water vessels or ornaments (Bertram 1992, Giazi et al. 2006). In addition, respondents claimed to use eggs in treatment of diseases such as asthma and tuberculosis, and use egg shells as ornaments during traditional dances and circumcision ceremonies. A worrying result is that ostrich eggs have become a commercial product, and some of the respondents claim that they are collected for sale, both to local villagers and tourists. Enforcing wildlife laws within these protected areas is therefore vital. Moreover, tourists should more explicitly be instructed to abide with wildlife regulations on the trade in wildlife products. This should be emphasised upon arrival at the entrance to protected areas. It may also be necessary to consider giving greater value to conserving bird species, through ecotourism-based operations and/or sustainable utilisation, as part of community-based conservation schemes in order to involve local people as stakeholders and to create incentives for conserving their avifauna.

Density

The density of ostriches within the partially protected areas was not significantly different from the density within the SNP. However, the areas outside the SNP differed in respect to vegetation types, containing more woodlands than the grassland dominated national park. This may have contributed to the observed densities. Other studies on mammals in the Serengeti ecosystem have found lower densities in the areas outside the national park and linked this to the widespread illegal bushmeat hunting conducted in the area (Dublin et al. 1990; Campbell and Borner 1995; Hofer et al. 1996; Rusch et al. 2005; Setsaas et al. 2007). In West Africa, Thiollay (2006a) reported that the decline of mammals caused illegal hunters to increasingly target large grassland birds. However, the Serengeti ecosystem still sustains large concentrations of herbivores, which may indicate that currently illegal hunters only kill large bird species opportunistically. Livestock grazing which occurs within the partially protected areas (legally within NCA and occasionally illegally inside the Grumeti and Ikorongo Game Reserves) may also cause changes to the habitat of birds and may damage the reproductive success of ground nesters through trampling and disturbance (Rodger and Smith 1997; Herremanns 1998; Lord et al. 2001). However, location of the transects may not have captured the full extent of possible effects of human activities, since they were mostly placed within the protected areas and relatively far from areas with high human density. Sinclair et al. (2002) noted that the abundance of species found in cultivated areas in relatively high human density areas in north-western Serengeti was only 28% of that for the same species in native savannah. This was mostly due to removal of trees and a decrease in grass-layer insect abundance and diversity. Also Thiollay (2006a) noted declines in bird diversity and abundance in high human density areas and that the disappearance of game birds also contributed to a dramatic decline in raptor species (Thiollay 2006c). The human population in both NCA and in the western Serengeti are growing rapidly, which means that human impact is likely to increase in the future

(Campbell and Hofer 1995; Boone et al. 2006). Considering the extensive use of birds it is therefore crucial that monitoring programs are expanded to also include the avifauna. This may serve to guide protected area managers to make more informed decisions about how to manage the location and size of human settlements within the NCA, as well as the level and type of human activity permitted (both NCA and Game Reserves) in order to ensure that biological values do not deteriorate.

Flight behaviour

The most parsimonious model indicated that two variables, starting distance and area, have a great influence on FID. This underlines that risk is assessed dynamically and that also ostriches flee at a greater distance as starting distance increases (Ydenberg and Dill 1986; Blumstein 2003). This response is probably stronger in large birds that rely solely on running to escape possible predators than in species that can fly, which might make them particularly vulnerable to disturbance (Gaston and Blackburn 1995; Fernández-Juricic et al. 2006; Blumstein 2006). Area also affected FID, but since illegal hunters do not currently specifically target ostriches and since the prevailing hunting method of illegal bushmeat hunters is snaring, it appears that ostriches might instead be negatively affected by the unregulated legal hunting. The partially protected areas in the west is subject to legal hunting from a number of government institutions (Holmern et al. 2004), where hunting of large herbivores is mostly conducted from vehicles. In some instances drivers chase animals over long distances, thus causing great distress to other wildlife species (Holmern, pers.obs. 2003); this may also cause ostriches also to become more flighty.

Conclusion

Our results suggest that illegal hunting currently does not affect ostriches adversely in the Serengeti ecosystem. However, observed changes in flight behaviour in the partially protected areas may have indirect fitness cost to the populations. On the other hand, the documented extensive hunting of small birds, collection and trade of eggs highlight that protected area managers need to develop clear strategies and policies for the location of human settlements, regulations for extraction of resources means to regulate human population size within protected areas. Human dominated habitats are expanding rapidly throughout Africa and other tropical areas (Campbell and Hofer 1995), and much of the avifauna can not coexist with humans (Sinclair et al. 2002). Thus, we recommend educational programs to make people aware of the importance of biodiversity and provision of agricultural incentives that may provide an alternative course of action.

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