



Illegal hunting and law enforcement during a period of economic decline in Zimbabwe: A case study of northern Gonarezhou National Park and adjacent areas

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ABSTRACT

Illegal hunting of wildlife, or top-down harvesting, is a major issue in today's society, particularly in tropical ecosystems. There has been widespread concern about increasing illegal hunting of wildlife in most conservation areas in Zimbabwe following the political instability and economic decline the country faced since 2000. In this study, we focused on the northern Gonarezhou National Park (GNP), a large and unfenced protected area, and adjacent communal areas in southern Zimbabwe. We hypothesised that illegal hunting activities would (1) be perceived to have increased due to economic collapse and (2) vary with law enforcement efforts. A total of 236 local residents from eight villages adjacent to the northern GNP were interviewed using semi-structured questionnaires from December 2010 to May 2011, and law enforcement data for northern GNP between 2000 and 2010 were retrieved from the park law enforcement database. A total of 26 animal species were reportedly hunted. Bushmeat consumption and the need for local trade to raise income were reported as the main reasons behind illegal hunting. Contrary to the first hypothesis, the majority of respondents ($n = 156$, 66%) reported that illegal hunting activities had declined between 2000 and 2010 largely due to increased park protection as also supported by law enforcement data. A total of 22 animal species were recorded as having been illegally hunted in northern GNP. The number of illegal hunters arrested declined with increased law enforcement efforts although the number of wire snares recovered and hunting dogs shot appeared to increase following increased law enforcement efforts. These results partly support the second hypothesis that illegal hunting activities would vary with law enforcement efforts.

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Introduction

In tropical areas, humans are commonly physically inseparable from natural systems due to the heavy dependence of local people on natural resources for their subsistence living (Robinson & Bennett 2004; Singh & Sharma 2009). However, this can lead to unsustainable forms of hunting. Illegal hunting, also known as poaching, is the taking of any kind of wildlife, including fish, in such a way that it violates local, national and international wildlife laws (e.g. Duffy 1999). Illegal hunting is often unsustainable and has led to reductions and/or local extinctions of many wildlife populations across the tropical ecosystems (Bennett et al. 2002; Bennett 2011; Ceballos & Ehrlich 2002; Corlett 2007; Emery 2007; Milner-Gulland

et al. 2003; Paudel & Kindlmann 2012; Peres 2000; Wilkie et al. 2011).

Illegal hunting involves the use of traditional hunting methods such as bow and arrows, snares, pitfalls (Kümpel et al. 2008; Noss 1998; Tumusiime et al. 2010), but also the illegal use of firearms, explosives, poisons and more recently small aircraft aided techniques and immobilisation drugs. Illegal hunting is particularly severe where rural people hunt within poorly managed protected areas (Fusari & Carpaneto 2006). Although law enforcement patrols attempt to control illegal hunting activities for bushmeat (meat derived from wild animals), and/or commercial sale within conservation areas (Jachmann 2008a, 2008b; Kaltenborn et al. 2008), the expected financial benefits from such activities are far greater than the costs associated with a low probability of arrest and punitive fines (Bennett 2011; Campbell & Hofer 1995; Loibooki et al. 2002; Moyle 2009). Illegal hunting is also influenced by a poor definition of property rights to wildlife species such as no owner (*res nullius*) status (Bulte & Horan 2002; Child & Chitsike 2000).

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When property rights are poorly defined, humans can be expected to expand their hunting effort as long as hunting is more beneficial (profitable) than alternative activities, or until there are zero profits in hunting for bushmeat (Bulte & Horan 2002). Enforcement efforts against wildlife trade in developing countries have generally been unstructured, unstrategic and underfunded; hence allowing the proliferation of illegal wildlife trade (Parr 2011).

Illegal hunting is a major problem throughout Africa (Barnes 2002; Brashares et al. 2011; de Boer et al. 2007; Fa & Brown 2009; MacKenzie 2012). Most illegal hunting studies in Africa have concentrated on central and western tropical forests on the mainland (Barnes 2002; Bennett et al. 2007; Brashares et al. 2004; Fa et al. 2006; Kümpel et al. 2010; Laurance et al. 2008; Wilkie & Carpenter 1999). Illegal hunting issues are increasingly receiving attention in the wildlife rich savanna and miombo woodlands of east and southern Africa as growing evidence suggests that illegal hunting represents high conservation threats in some parts of these regions (Barnett 2000; Fusari & Carpaneto 2006; Golden 2009; Hayward 2009; Jenkins et al. 2011; Lindsey et al. 2011; Nyahongo et al. 2009).

Publicly or state owned protected areas are common property regimes which are set aside for the benefit of society, with the main purpose being the conservation of biodiversity (Clerici et al. 2007; Gaston et al. 2008; Holland 2012; Naughton-Treves et al. 2005). However, disturbances associated with political unrests and economic collapse may result in increased illegal hunting (De Merode et al. 2007; Kanyamibwa 1998; Rowcliffe et al. 2004; Yamagiwa 2003) due to weak policy instruments associated with poor management of natural resources (Bunnefeld et al. 2011). Policy instruments are important in the management of common pool resources, such as wildlife resources, and addressing social dilemmas (Leeuwis & van den Ban 2004). Social dilemmas are situations in which autonomous individuals act in their own rational self-interest, yet the collective outcomes of these independent actions threaten misfortune to all (Karp & Gaulding 1995; Ostrom 2010). Collapse in law enforcement can result in a protected area becoming more characteristic of an open access resource, therefore, leading to a situation reminiscent of what has been classically called "tragedy of the commons" (Berkes et al. 1989; Hardin 1968) where individuals from local communities maximise gain from wildlife resources through increased illegal hunting (Sibanda 1995). Such increased illegal hunting activities, a form of wildlife crime, often leads to species becoming overexploited to increase short-term profits while endangering and eliminating a natural resource for future users (Pires & Moreto 2011). Past studies suggest that illegal hunting activities seem to vary with law enforcement efforts. For instance, poor law enforcement efforts have been linked to declines in wildlife populations as a result of increased illegal hunting (Bassett 2005; Ogutu et al. 2011). In contrast, improved law enforcement efforts have been associated with a reduction in illegal hunting activities (Jachmann 2008a, 2008b; Leader-Williams et al. 1990; Martin 2010). Furthermore, illegal hunting activities have been reported to decrease with an increase in: (i) distance from a protected area boundary (Wilfred & MacColl 2010) and (ii) benefits accrued by local communities from wildlife conservation (Johannesen 2006). In contrast, illegal hunting activities have been reported to increase with an increase in human population density inside or adjacent to a protected area (Metzger et al. 2010; Newmark 2008).

Previous studies provide evidence which suggests that illegal hunting has emerged as a serious conservation threat in Zimbabwe (Duffy 1999; Mapedza & Bond 2006; Wolmer 2005), particularly in fenced privately owned conservation areas that were negatively affected by the land reform process which began in 2000 (Chaumba et al. 2003; Degeorges & Reilly 2007; Lindsey et al. 2011; Wels 2003; Williams 2011). However, there is a gap in literature concerning the extent of illegal hunting and law enforcement efforts in state

protected areas in Zimbabwe. These areas are largely unfenced and were less affected by the land reform process since they were not targeted for resettlement under the fast track land reforms. In the current study we attempt to contribute to the understanding of illegal hunting in a state owned protected area bordering communal areas implementing community based natural resources management programmes, namely Communal Areas Management Programme for Indigenous Resources (CAMPFIRE), using a case study from southern Zimbabwe. Wildlife in Zimbabwe is *res nullius* (Cumming 1999). State protected areas in Zimbabwe, particularly national parks, differ from private protected areas in that they have lower manpower levels, fewer financial resources for conservation and are bordered by communal areas which mostly have CAMPFIRE programmes that help local communities and natural resources conservation.

This study focuses in the period covering the political instability and economic decline in Zimbabwe. Between 2000 and 2008, Zimbabwe faced a severe economic crisis (Coltart 2008). The national currency was drastically devalued and the cost of living rose continually (Hanke & Kwok 2009). Many communities especially those in remote areas and around protected areas were left suffering high unemployment and shortages of food and other basic supplies (Coltart 2008). Although sport-hunting in CAMPFIRE areas continued, the cash dividends to local people had little impact on relief of hardships (e.g. Balint & Mashinya 2006). This study therefore concentrates on the largest national park in southern Zimbabwe, namely the northern Gonarezhou National Park (GNP) and adjacent local communities. Specifically, we hypothesised that illegal hunting activities would (1) be perceived to have increased due to economic collapse and (2) vary with law enforcement efforts.

Materials and methods

Study area

Criteria used to select the study area were (i) a large and unfenced protected area (national park) in southern Zimbabwe and (ii) existence of local communities with community based natural resources management programmes adjacent to the protected area. The northern GNP, namely Chipinda Pools and four wards comprising, Chibwedziva and Chizvirizvi falling under the Chiredzi district, and Mahenye and Mtandahwe falling under the Chipinge district, all adjacent to the northern GNP in southeastern Zimbabwe were selected (Fig. 1). Established in the early 1930s as a Game Reserve, GNP was upgraded to a national park under the Parks and Wildlife Act of 1975. GNP was initially fenced during the early 1970s but by the 1990s, most of the fence was lost to vandalism and theft. The study area forms part of the Great Limpopo Trans-frontier Conservation Area. The GNP is the second largest national park in Zimbabwe after Hwange National Park and covers an area of approximately 5000 km² and is located between 21°00'–22°15'S and 30°15'–32°30'E.

There is a wide variety of large herbivore species in the GNP and these include the African elephant (*Loxodonta africana*), hippopotamus (*Hippopotamus amphibius*), African buffalo (*Synacerus caffer*), giraffe (*Giraffa camelopardalis*), plains zebra (*Equus quagga*), waterbuck (*Kobus ellipsiprymnus*), roan antelope (*Hippotragus equinus*), sable antelope (*Hippotragus niger*), blue wildebeest (*Connochaetes taurinus*), eland (*Taurotragus oryx*), kudu (*Tragelaphus strepsiceros*), nyala (*Tragelaphus angasi*) and impala (*Aepyceros melampus*). The park is also endowed with a variety of large carnivores including the African lion (*Panthera leo*), leopard (*Panthera pardus*) and spotted hyena (*Crocuta crocuta*) (Gandiwa 2012).

The dominant ethnic group in the study area is Shangaan. Local residents in communities adjacent to the northern GNP practice

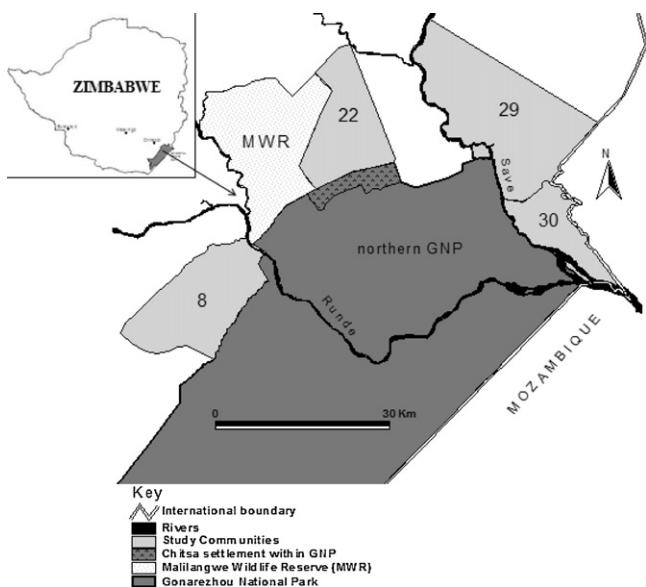


Fig. 1. Location of the four study wards adjacent to the northern Gonarezhou National Park, south-eastern Zimbabwe. Notes: 8 – Chibwedziva ward, 22 – Chizvirizivi ward, 29 – Mtandahwe ward and 30 – Mahenye ward.

a combination of subsistence, cash crop farming and livestock production (Gandiwa 2011). These communities manage their natural resources under CAMPFIRE programmes implemented since 1982 in an effort to generate benefits for local communities that otherwise had been deprived by protection policies (Child 1993; Murphree 1988).

Data collection

Perceptions of illegal hunting and protected area law enforcement

Data on local people's perceptions of illegal hunting were collected from eight villages occurring in the four study wards, i.e. two villages per ward, using semi-structured questionnaires administered through face-to-face interviews from December 2010 to May 2011. Perceptions are important because they reflect local people's habitual way of life, as well as their shared expectations or experiences with an activity (Uddin & Foisal 2007). Current village registers of the selected eight study villages formed the sampling pool and households were randomly selected through picking of numbers from a hat that corresponded to the households from each study village register. The household heads were targeted as the respondents. In case of their absence, another permanently resident adult (≥ 18 years) in the households took part in the interview in his/her residence. Interviews were conducted conditionally upon the individual's willingness to fully participate. Respondents were local villagers and no distinction was made between hunters and non-hunters. This was done to encourage local residents to openly provide illegal hunting information which can be regarded as sensitive.

The date for interview was communicated to each selected household one or two days in advance. Our questionnaire development was informed by a previous survey of perceptions of illegal hunting in southeastern Zimbabwe (Gandiwa 2011). Questions were constructed to seek information on the general perceptions of illegal hunting practices inside the GNP and adjacent areas between 2000 and 2010. Data collected included information on frequency of sighting bushmeat and/or wild animal products being traded, perceptions of illegal hunting trends, hunted animal species, reasons for hunting, and perceptions of protection status in the protected area (Table 1). With the help of one field assistant conversant in

Table 1

Outline of the semi-structured questionnaire used in the household survey in the four study wards adjacent to northern Gonarezhou National Park, Zimbabwe.

Questions	Options provided
Between 2000 and 2010, how often did you see bushmeat or wild animal products being traded in your village or ward?	Once in 30 days/once between 31 and 180 days/once in >6 months/year Increased/decreased/remained the same
In your opinion, what is the trend of illegal hunting of wild animals in your ward and adjacent Gonarezhou National Park in the last eleven years, i.e. between 2000 and 2010?	Open
What are the reasons for the given trend in illegal hunting?	Open
May you list the wild animal species that were commonly hunted illegally in your ward and nearby Gonarezhou National Park between 2000 and 2010?	Open
In your opinion what are the main reasons why people engage in illegal hunting activities in the area?	Open
What do you think is the trend of protection given to wildlife conservation by the government between 2000 and 2010?	Increased/decreased/remained the same

local language acting as a translator, we interviewed a total of 236 local residents, who consisted of 146 (62%) men and 90 (38%) women. Interviews took on average approximately 54 min (range: 38–76 min) to complete.

Protected area law enforcement and illegal activities

We extracted law enforcement data on patrol intensity and evidence of illegal activities in northern GNP for the period 2000–2010 from the law enforcement database kept at Chipinda Pools in GNP. GNP uses the conventional law enforcement in the form of foot patrols that start from each of the ranger camps as well as from the stations' main and sub-offices. Almost all local (day) and long (over several days) patrols are done during the day in the GNP. Only strategic or ambush patrols may extend to the night with patrol rangers remaining in one particular location, often near a frequently used poaching trail, but sometimes in response to intelligence information. Standardised patrol forms were used to keep records of the number of staff on patrol, the exact duration, the area travelled, types, quantities and locations of illegal activity encountered including number of hunters and dogs, number caught, or shot in the case of dogs, number of snares recovered, number and species of animals killed in each incident. The method of conventional law enforcement has been discussed fully elsewhere (Jachmann 2008a, 2008b; Jachmann et al. 2011).

A patrol team in Chipinda Pools normally has four or five patrol rangers. This patrol team size is considered appropriate in savanna ecosystems (Jachmann 2008a, 2008b). In northern GNP, patrol data were checked at debriefing by the Senior Rangers, then by the Senior Wildlife Officer in charge of law-enforcement operations before being captured into a law enforcement database. The relationships between the law-enforcement effort and encounters with illegal activity and wildlife assume that patrol reports are reliable accounts of the activities of the patrol staff, both in terms of technical precision and in terms of being a true account of events (Jachmann 2008a). The law enforcement data for GNP revealed that the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) recruited additional patrol rangers in the year 2004. Furthermore, data on large herbivore population estimates for the northern GNP (i.e. Chipinda Pools, Chilojo A and Chilojo B aerial survey strata), for 2001 and 2009, were extracted from past aerial survey reports (Dunham 2002; Dunham et al. 2010).

Data analysis

Chi-square (χ^2) tests for goodness-of-fit were used to test whether responses on the prevalence of illegal hunting, perceived illegal hunting trends and protection given by the government to wildlife between 2000 and 2010 were different among the 236 respondents using SPSS version 19 for Windows (SPSS Inc., Chicago, USA). We used the response categories outlined in Table 1 in the Chi-square tests. Cross-tabulation with gamma (G) test were used to establish the association between responses on: (i) prevalence of illegal hunting and perceived illegal hunting trends; (ii) prevalence of illegal hunting and protection given by government to wildlife; and (iii) perceived illegal hunting trends and protection given by government to wildlife. We further examined trends in law enforcement performance and illegal activities in northern GNP from 2000 to 2010 to reveal patterns during the period of political instability and economic collapse. Law enforcement performance was evaluated using two measures, namely (i) effective patrol staff density (i.e. number of patrol rangers per km²) and (ii) effective patrol days/staff/month derived from effective patrol man-days (Jachmann 2008a, 2008b). For the northern GNP, the only readily available patrol data were from long or extended patrols. Effective patrol days for long patrols in northern GNP are indirectly measured by the patrol nights spent by each ranger. Effective patrol time was standardised and converted directly from patrol nights to effective patrol days which were later converted to effective patrol days/staff/month. We examined whether law enforcement performance and illegal activities differed in the two periods, i.e. 2000–2003 and 2004–2010 following the recruitment of more patrol staff in northern GNP in 2004, using independent samples two-tailed *t*-tests with unequal sizes.

In order to assess the overall effect of law enforcement performance on illegal activities between 2000 and 2010 in northern GNP, we used repeated measures analysis of variance (ANOVA), with law enforcement performance and time (year) as independent variables and illegal activities (hunting and fishing) as dependant variables. Data on effective patrol staff density, arrested bushmeat hunters and fish poachers were log₁₀ ($x+1$) transformed to meet the normality requirements of ANOVA tests. Furthermore, for common large herbivore species in northern GNP, we calculated percentage population size changes using population estimate data from 2001 to 2009 in order to determine whether animal populations were increasing, decreasing or remained the same.

Results

Perceptions of illegal hunting in northern GNP between 2000 and 2010

Responses on perceptions of illegal hunting trends between 2000 and 2010 varied among the 236 respondents ($\chi^2 = 114.14$, df = 2, $P < 0.0001$). A higher proportion of the respondents ($n = 156$, 66%) perceived that illegal hunting activities had declined whereas 18% ($n = 42$) of the respondents perceived that illegal hunting activities had increased and 16% ($n = 38$) of the respondents perceived that illegal hunting activities had remained the same in the study area between 2000 and 2010. The main reasons for the perceived decline in illegal hunting were reported to include; (i) that poachers were afraid of being arrested or imprisoned due to strengthened law enforcement ($n = 173$, 73%), (ii) the positive impact of conservation awareness and educational programmes ($n = 62$, 26%), and (iii) few firearms were available for use in illegal hunting ($n = 8$, 3%).

Similarly, responses on the frequency of sighting illegally hunted animals and/or bushmeat being traded in the villages between 2000 and 2010 varied among the 236 respondents

($\chi^2 = 15.31$, df = 2, $P < 0.001$). A higher proportion of the respondents ($n = 107$, 45%) reported that they had sighted illegal hunted animals or bushmeat being traded at least once over six months whereas 28% ($n = 65$) and 27% ($n = 64$) of the respondents reported that they had sighted illegal hunted animals or bushmeat being traded at least once between 31 and 180 days, and once in a month respectively. There was a significant relationship between responses on the frequency of sighting illegally hunted animals and/or bushmeat being traded and the perceived illegal hunting trends ($\text{gamma} = 0.34$, $P = 0.002$).

Animal species hunted and reasons for them being hunted

A total of 26 wild animal species, including large herbivores and carnivores, were reported as being illegally hunted in northern GNP between 2000 and 2010, with impala, kudu, buffalo, zebra and spotted hyena being the most hunted (Table 2). Respondents highlighted seven reasons why local people were involved in illegal hunting, namely, (i) the need for bushmeat for domestic consumption ($n = 162$, 69%), (ii) local trade in bushmeat in order to raise money ($n = 132$, 56%), (iii) as a way to minimise crop damage ($n = 42$, 18%) and (iv) livestock depredation ($n = 24$, 10%), (v) hunting for traditional reasons ($n = 24$, 10%), (vi) unemployment ($n = 10$, 4%), and (vii) hunting as a hobby ($n = 7$, 3%).

Perceptions by locals of protection given to wildlife by the government

About 46% ($n = 108$) of the total respondents perceived that protection given by the government to wildlife had increased between 2000 and 2010 in northern GNP whereas 37% ($n = 88$) and 17% ($n = 40$) of the respondents perceived that protection given by government to wildlife had remained the same and decreased respectively. These responses significantly varied among the 236

Table 2

Animal species reported to be commonly hunted illegally in northern Gonarezhou National Park and adjacent areas, Zimbabwe, between 2000 and 2010. Total percentage exceeds 100 because the respondents were allowed to give multiple answers.

Common name	Scientific name	Number of responses	Percentage (%)
Impala	<i>Aepyceros melampus</i>	126	53
Kudu	<i>Tragelaphus strepsiceros</i>	119	50
Buffalo	<i>Synacerus caffer</i>	110	47
Zebra	<i>Equus quagga</i>	81	34
Spotted hyena	<i>Crocuta crocuta</i>	77	32
Wildebeest	<i>Connochaetes taurinus</i>	57	24
Elephant ^V	<i>Loxodonta africana</i>	46	19
Warthog	<i>Phacochoerus africanus</i>	45	19
Leopard ^{NT}	<i>Panthera pardus</i>	42	18
Eland	<i>Taurotragus oryx</i>	40	17
Lion ^V	<i>Panthera leo</i>	31	13
Common duiker	<i>Sylvicapra grimmia</i>	20	9
Waterbuck	<i>Kobus ellipsiprymnus</i>	20	9
Giraffe	<i>Giraffa camelopardalis</i>	20	9
Nyala	<i>Tragelaphus angasii</i>	19	8
Bushbuck	<i>Tragelaphus scriptus</i>	19	8
Cheetah ^V	<i>Acinonyx jubatus</i>	17	7
Steenbok	<i>Raphicerus campestris</i>	14	6
Reedbuck	<i>Redunca redunca</i>	12	5
Baboon	<i>Papio ursinus</i>	11	5
Hippopotamus ^V	<i>Hippopotamus amphibius</i>	11	5
Nile crocodile ^{LR}	<i>Crocodylus niloticus</i>	10	4
Klipspringer	<i>Oreotragus oreotragus</i>	10	4
Sable	<i>Hippotragus niger</i>	8	3
Common genet	<i>Genetta genetta</i>	5	2
Porcupine	<i>Hystrix cristata</i>	2	1

Notes: Species categorised as Vulnerable: V, Lower Risk: LR and Near-Threatened: NT on the 2011 IUCN (International Union for the Conservation of Nature) Red List (IUCN 2012).

respondents ($\chi^2 = 31.05$, df = 2, $P < 0.0001$). However, the relationship between responses on the frequency of sighting illegally hunted animals and/or bushmeat being traded and protection given by government to wildlife was not significant ($\text{gamma} = 0.07$, $P = 0.455$). In contrast, there was a significant relationship between responses on the perceived illegal hunting trends and protection given by government to wildlife ($\text{gamma} = 0.23$, $P = 0.028$).

Law enforcement performance from law enforcement data

In 2000, a total of 18 patrol rangers were stationed at Chipinda Pools, northern GNP translating to 0.006 effective patrol staff/km² (Fig. 2a). The number of patrol rangers increased to 51 in 2004 following the recruitments of new rangers (0.017 effective patrol staff/km²) and by end of December 2010, there were 38

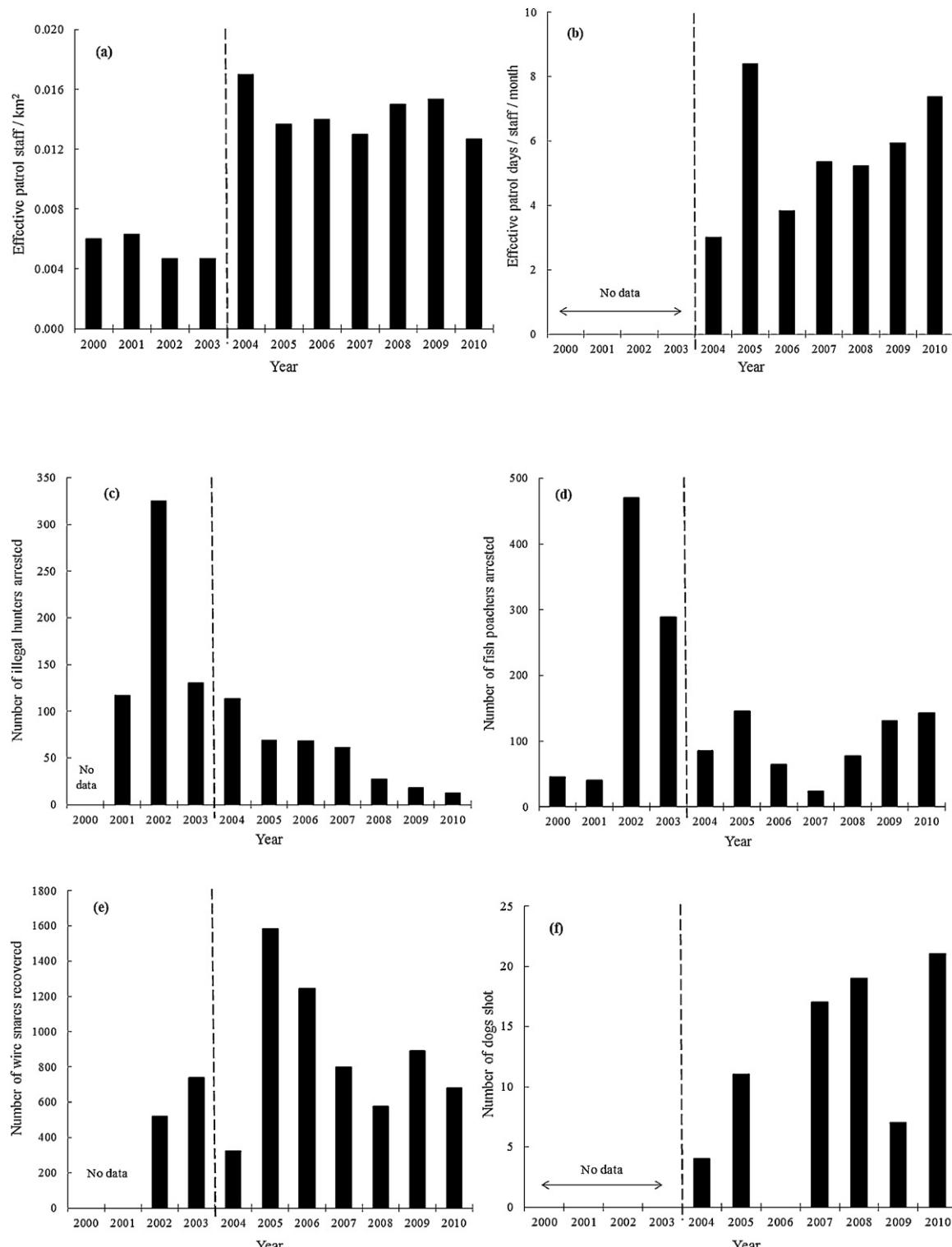


Fig. 2. Trends in law enforcement performance and recorded illegal activities in Chipinda Pools, northern Gonarezhou National Park, Zimbabwe, from January 2000 to December 2010. Notes: Dashed vertical lines separate the period before and after recruitments of patrol rangers.

patrol rangers in Chipinda Pools (0.013 effective patrol staff/km 2 ; Fig. 2a). The mean number of effective patrol staff/km 2 was significantly higher for the period 2004–2010 (mean and standard error: 0.014 ± 0.001) compared to 2000–2003 (0.005 ± 0.0004) ($t = -10.74$, df = 9, $P < 0.0001$). The slight decline in available patrol rangers in Chipinda Pools between 2004 and 2010 was a result of transfers, resignations, retirements and/or natural deaths. Data for patrol days were unavailable for the period 2000–2003. In 2004, staff performance was 3.0 effective patrol days/staff/month but it gradually improved to 7.4 effective days/staff/month in 2010 (mean = 5.59 ± 0.71). The high peak in 2005 coincides with an increase in patrol rangers and patrols in northern GNP (Fig. 2b).

Illegal activities recorded from law enforcement patrols

A total of 940 illegal hunters and 1509 illegal fish poachers were captured, 79 hunting dogs were shot and 7340 wire snares were recovered between 2000 and 2010 in northern GNP. Illegal activities, mainly illegal fishing and hunting, in the northern GNP were high between 2000 and 2003, and declined towards 2010 (Fig. 2c and d). The peak in hunter and illegal fisher arrests in 2002 was associated with increased patrols following human settlement encroachments within the north-western GNP. The mean number of illegal hunters arrested were significantly lower for the period 2004–2010 (53 ± 14) compared to the period 2000–2003 (191 ± 67) ($t = 3.03$, df = 8, $P = 0.016$). The mean number of illegal fish poachers arrested did not differ significantly between the period 2000–2003 (211 ± 104) and 2004–2010 (95 ± 17) ($t = 1.47$, df = 9, $P = 0.176$). The mean number of wire snares recovered did not differ between the period 2000–2003 (628 ± 111) and 2004–2010 (896 ± 160) ($t = -0.76$, df = 7, $P = 0.474$; Fig. 2e). Data for number of dogs shot were unavailable for the period 2000–2003. Four dogs were shot in 2004 and this increased to 21 in 2010 (Fig. 2f). The repeated-measures ANOVA results, with a Greenhouse-Geisser epsilon correction for lack of sphericity in the variance-covariance matrix, indicated no significant illegal activities \times year ($F_{1,3,001} = 1.61$, $P = 0.293$), illegal activities \times effective patrol days/staff/month ($F_{1,3,001} = 0.95$, $P = 0.403$) or illegal activities \times effective staff density/km 2 ($F_{1,3,001} = 0.62$, $P = 0.488$) interactions between 2000 and 2010.

About 499 animals of 22 species were illegally killed between January 2001 and December 2010 (Table 3). Patrol reports showed that most animals were killed by snaring using steel cables from the old cattle veterinary fence, stolen telephone and electricity overhead cables, and old boundary fence. Other hunting methods recorded were using bow and arrows, hunting dogs, firearms mostly for elephants, and poisoning. Impala, kudu and elephants were the most common illegally hunted animals in northern GNP between 2001 and 2010. Large carnivores, namely lion and spotted hyenas were amongst the least illegally killed species. Overall, only 20 animal species were common among the reportedly illegally hunted animals and those that were recorded to have been illegally hunted. Differences in the recorded illegally killed animals and animals perceived to be commonly hunted illegally (Table 2) in northern GNP include four animal species (bushbuck, reedbuck, klipspringer and sable) that were not recorded among the illegally hunted animals. In addition, two animal species (Sharpe's Grysbok and slender mongoose) that were recorded as illegally hunted were not reported to be illegally hunted. Despite the illegal hunting of primarily large herbivores in the northern GNP, most of the large herbivores showed increasing populations sizes between 2001 and 2009. Nyala (+727%), eland (+269%), zebra (+126%) and elephant (+111%) were amongst the species with the highest population size increases (Table 4).

Table 3

Animals recorded lost to illegal hunting in Chipinda Pools, northern Gonarezhou National Park, Zimbabwe, from January 2001 to December 2010, based on law enforcement data. Notes: BW – bow and arrow; F – fire arm; HD – hunting dogs; P – Poison; and S – snaring.

Common name	Scientific name	Total killed	Hunting method used
Impala	<i>Aepyceros melampus</i>	194	S/HD
Kudu	<i>Tragelaphus strepsiceros</i>	58	S/HD
Elephant ^V	<i>Loxodonta africana</i>	54	F/S
Nyala	<i>Tragelaphus angasii</i>	31	S/HD
Zebra	<i>Equus quagga</i>	27	S
Warthog	<i>Phacochoerus africanus</i>	21	S/HD
Eland	<i>Taurotragus oryx</i>	18	S
Buffalo	<i>Synacerus caffer</i>	16	S
Wildebeest	<i>Connochaetes taurinus</i>	13	S
Common duiker	<i>Sylvicapra grimmia</i>	11	S/HD
Waterbuck	<i>Kobus ellipsiprymnus</i>	11	S/HD
Giraffe	<i>Giraffa camelopardalis</i>	9	S
Steenbok	<i>Raphicerus campestris</i>	7	S/HD
Baboon	<i>Papio ursinus</i>	6	HD
Sharpe's Grysbok	<i>Raphicerus sharpei</i>	5	S/HD
Hippopotamus ^V	<i>Hippopotamus amphibius</i>	5	P
Spotted hyena	<i>Crocuta crocuta</i>	3	P
Porcupine	<i>Hystrix cristata</i>	3	BW
Nile crocodile ^{LR}	<i>Crocodylus niloticus</i>	2	P
Lion ^V	<i>Panthera leo</i>	2	S
Slender mongoose	<i>Galerella sanguinea</i>	2	HD
Common genet	<i>Genetta genetta</i>	1	HD
Total	—	499	—

Notes: Species categorised as Vulnerable: V and Lower Risk: LR on the 2011 IUCN Red List (IUCN 2012).

Discussion

Local people near protected areas in tropical ecosystems adapt to disturbances or hardships caused by economic collapse, social unrest, military or political conflict through migration or diversifying income, including illegal fishing and hunting (Beyers et al. 2011; Brashares et al. 2011; De Merode et al. 2007; Draulans & Van Krunkelsven 2002; Fusari & Carpaneto 2006; Yamagiwa 2003). Contrary to perceived collapse of wildlife management systems in Zimbabwe since 2000 (The Guardian 2008), our results show that law enforcement performance was strengthened in 2004 in the northern GNP which could have resulted in the overall perceived decline in illegal activities by the study respondents. The then Department of National Parks and Wildlife Management was transformed into a parastatal, namely ZPWMA starting in 2000 following the amendment of Zimbabwe's Parks and Wildlife Act (1975) with full implementation in 2002 (Mtsambwi 2003). This transformation resulted in a direct increase in funds available for wildlife management since income generated by the ZPWMA no

Table 4

Estimated population sizes (\pm standard errors) and percentage change in common wild animals between 2001 and 2009 in northern Gonarezhou National Park, Zimbabwe. Notes: n.a. – not available; dash (–) denotes not applicable.

Common name	2001	2009	Percentage change (%)
Nyala	37 ± 12	306 ± 49	+727
Eland	74 ± 25	273 ± 84	+269
Zebra	286 ± 84	647 ± 109	+126
Elephant	2628 ± 441	5543 ± 386	+111
Waterbuck	168 ± 50	326 ± 109	+94
Kudu	889 ± 166	1445 ± 337	+63
Giraffe	60 ± 12	95 ± 21	+58
Impala	2432 ± 294	3660 ± 630	+50
Buffalo	919 ± 216	1163 ± 337	+27
Wildebeest	n.a.	266 ± 51	–

Source: Dunham (2002) and Dunham et al. (2010).

longer went to the central government but was directly channelled to conservation (Mtsambiwa 2003). Sport-hunting has been the major revenue source for the ZPWMA and other local conservation areas. Surprisingly, sport-hunting was not severely affected by the political instability and economic decline in Zimbabwe (Balint & Mashinya 2006; Lindsey et al. 2009). Consequently, ZPWMA was able to enhance wildlife protection in the northern GNP by increasing the number of patrol rangers in 2004 (from 18 to 51 rangers). However, in terms of personnel, the coverage area per ranger in 2010, i.e. one ranger for every 79 km² of protected area, is far higher than the recommended minimum of one park ranger for every 24 km² of protected area if effective patrolling and policing is to be realised (Jachmann & Billiouw 1997). Furthermore, anti-poaching efforts in the northern GNP were also strengthened by the involvement of the Frankfurt Zoological Society in the management of the park since October 2007, which led to more resources being made available for law enforcement activities. The recurrent expenditure for law enforcement in northern GNP rose from USD 52 per km² annually in 2000 to USD 250 per km² annually in 2010. The increase in law enforcement expenditure is above the minimum range of expenditure estimated to be between USD 50 and 200 per km² annually that wildlife agencies in Africa need to protect large herbivores, in particular elephants, in their natural ranges (Jachmann & Billiouw 1997).

We recorded that illegal hunters hunted a wide range of animal species in this study. Out of the 26 animal species reported as being illegally hunted, 20 animal species were recorded as having been illegally killed in GNP. Differences in the number of animal species most illegally hunted are likely come from the fact that most of the animal species that were not recorded as illegally hunted are small herbivores, which are difficult to detect when illegally hunted. Our study shows that small to medium body sized animals, for example impala, were the most illegally hunted species. Subsistence hunting is primarily targeted at small-bodied species like impala with large-bodied animals such as elephants targeted for their trophies such as ivory. Some of the illegally hunted species in the northern GNP are of conservation concern: crocodile is classified as lower risk; elephant, lion, cheetah, hippopotamus are classified as vulnerable, and leopard is classified as near threatened on the IUCN Red List (IUCN 2012). Using a vulnerability classification approach based on species vulnerability to decline and extinction involving opinions from international and local experts, Van der Hoeven (2007) categorised leopard as least concern, buffalo as lower risk and elephant as vulnerable. The differences in these two vulnerability classifications points to the need for more detailed local assessments of animal species that allows the setting of appropriate local level conservation priorities (Van der Hoeven 2007).

Hunting for wild animals in the northern GNP is, just like in other regions across the globe, stimulated by the need to meet nutritional, economic, cultural and recreational requirements (Bitanyi et al. 2012; Brashares et al. 2011; Golden et al. 2011; Grey-Ross et al. 2010; Hofer et al. 2000; Rao et al. 2005; Wilkie et al. 2011). Subsistence hunting is done mainly for domestic consumption or for selling within the community (Gandiwa 2011). The reasons given for illegal hunting in the present study suggest that the main drivers of bushmeat hunting and trade include need for bushmeat, money and unemployment. Our study contributes to the increasing evidence for illegal hunting in protected areas throughout Africa for the bushmeat trade, particularly in southern Africa.

Our results show that with increased illegal hunter's arrests, there was a shift to snaring as more wire snares were recovered by law enforcement staff. Snares are regarded as the simplest and most effective hunting devices (Fa & Brown 2009; Hurt & Ravn 2000; Jachmann 2008b). It has been suggested that, with increased law enforcement efforts in an area, illegal hunters were likely to switch to less detectable methods such as snaring, and target

smaller sized mammals such as impala (Gibson & Marks 1995). Elsewhere, in the Serengeti National Park, Tanzania, illegal hunters were reported to use a variety of hunting methods with snaring being the common hunting method (Holmern et al. 2007; Hurt & Ravn 2000; Nyahongo et al. 2005). However, in areas outside the Serengeti National Park, where law enforcement was regarded as low, hunters were reported to actively stalk their prey (Holmern et al. 2006) and use other hunting methods such as guns, spears, and bow and arrows. Furthermore, Ngurdoto Crater, which was nearly as rich in wildlife as Ngorongoro Crater, also in Tanzania, lost its wildlife due to illegal hunting with dogs that were kept in underground pens to prevent discovery in the 1970s and 1980s (H.H.T. Prins, personal observation).

Our results using law enforcement and large herbivore population data from the northern GNP suggest that pressure from illegal hunting is light as some large herbivore populations increased in population sizes between 2001 and 2009 despite a total of approximately 500 wild animals having been illegal hunted between 2000 and 2010, and also the recorded human settlement encroachments in a small portion of north-western GNP (Gandiwa et al. 2011; Mombeshora & Le Bel 2009). In contrast, it has been reported that most wildlife population declines following the political instability and economic decline in Zimbabwe since 2000 were recorded in private game ranches or farms following widespread poaching associated with the land invasions and collapse of law enforcement systems in some areas (Chaumba et al. 2003; Degeorges & Reilly 2007; Wels 2003; Williams 2011; Wolmer 2005). Elsewhere, in much of tropical rainforest ecosystems populations of many large bodied wildlife species have already declined or were extirpated because of habitat loss and hunting, leaving a fauna consisting predominantly of resilient, rapidly reproducing species (Barnes 2002; Bennett et al. 2007; Harrison 2011; Peres 2000, 2001; Van der Hoeven 2007; Wilkie et al. 2011). Therefore, evaluating the sustainability of hunting is key to the conservation of species exploited for bushmeat (Ling & Milner-Gulland 2006; Milner-Gulland & Akçakaya 2001). Because large body size is correlated with slow breeding, large animals would be more susceptible to extinction under any environmental or anthropogenic impact that targeted slow breeders (Koch & Barnosky 2006).

Although there was an economic collapse in Zimbabwe (Colart 2008), the country fell back to a subsistence economy, in which there was only limited violence and no refugees, and this may have prevented an increase in illegal hunting over the study period. Furthermore, remittances from those who had migrated outside of Zimbabwe played an important role in the day-to-day survival of local people (Makina 2012) and could also have eased the demand for trade in bushmeat to raise income. Similarly, the emigration of local people living adjacent to the GNP to neighbouring countries, mostly South Africa and Mozambique, to look for employment and/or to commercial farms under the land reform programme could have led to a decline in illegal hunting pressure in the GNP. Elsewhere, in the Central African Republic (Blom et al. 2005), Democratic Republic of Congo (Beyers et al. 2011; Draulans & Van Krunkelsven 2002; Yamagiwa 2003), and Rwanda (Kanyamibwa 1998), human conflicts such as civil wars and economic collapse led to substantial negative impacts on wildlife and conservation, resulting in significant losses of wildlife due to institutional collapse, lawlessness and uncontrolled exploitation of natural resources such as bushmeat.

Our study shows that political instability and economic collapse do not necessarily lead to increased hunting in situations where policy instruments, such as law, are enforced. In addition, increasing law enforcement helped minimise the level of illegal hunting in GNP. Therefore, over an 11-year period (i.e. 2000–2010), our study does not support the first hypothesis that illegal hunting activities would be increased due to economic collapse. However, our

results showed that in the initial phase, i.e. 2000–2003, we did see a reduction in law enforcement and when law enforcement increased in 2004, illegal hunting activities, particularly the number of arrested bushmeat hunters, decreased. These changes in the levels of illegal hunting activities and law enforcement efforts partly supports the second hypothesis that illegal hunting activities would vary with law enforcement efforts. Hence, effective enforcement of wildlife laws is important for the conservation of wildlife resources (Bruner et al. 2001; Holmern et al. 2007; Keane et al. 2008; Rowcliffe et al. 2004). Our study showed that snaring appeared to be one of the common hunting methods in the northern GNP. Snares could therefore be collected more effectively if there is a ranger team specialising in snare search patrols (Wato et al. 2006). Therefore, there is need for the ZPWMA to increase its ranger staffing levels to allow for effective patrolling and policing of the northern GNP to be realised.

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References

- Balint, P., & Mashinya, J. (2006). The decline of a model community-based conservation project: Governance, capacity, and devolution in Mahenye, Zimbabwe. *Geoforum*, 37, 805–815.
- Barnes, R. F. W. (2002). The bushmeat boom and bust in West and Central Africa. *Oryx*, 36, 236–242.
- Barnett, R. (2000). *Food for thought: The utilization of wild meat in Eastern and Southern Africa*. Nairobi: TRAFFIC/WWF/IUCN.
- Bassett, T. J. (2005). Card-carrying hunters, rural poverty, and wildlife decline in Northern Côte d'Ivoire. *The Geographical Journal*, 171, 71–82.
- Bennett, E. L. (2011). Another inconvenient truth: The failure of enforcement systems to save charismatic species. *Oryx*, 45, 476–479.
- Bennett, E. L., Blencowe, E., Brandon, K., Brown, D., Burn, R. W., Cowlishaw, G., et al. (2007). Hunting for consensus: Reconciling bushmeat harvest, conservation, and development policy in west and central Africa. *Conservation Biology*, 21, 884–887.
- Bennett, E. L., Milner-Gulland, E., Bakarr, M., Eves, H. E., Robinson, J. G., & Wilkie, D. S. (2002). Hunting the world's wildlife to extinction. *Oryx*, 36, 328–329.
- Berkes, F., Feeny, D., McCay, B. J., & Acheson, J. M. (1989). The benefits of the commons. *Nature*, 340, 91–93.
- Beyers, R. L., Hart, J. A., Sinclair, A. R. E., Grossmann, F., Klinkenberg, B., & Dino, S. (2011). Resource wars and conflict ivory: The impact of civil conflict on elephants in the Democratic Republic of Congo—The case of the Okapi Reserve. *PLoS One*, 6, e27129, doi:27110.21371/journal.pone.0027129.
- Bitanyi, S., Nesje, M., Kusiluka, L. J. M., Chonyambuga, S. W., & Kaltenborn, B. P. (2012). Awareness and perceptions of local people about wildlife hunting in western Serengeti communities. *Tropical Conservation Science*, 5, 208–224.
- Blom, A., Van Zalinge, R., Heitkönig, I. M. A., & Prins, H. H. T. (2005). Factors influencing the distribution of large mammals within a protected central African forest. *Oryx*, 39, 381–388.
- Brashares, J. S., Arcese, P., Sam, M. K., Coppolillo, P. B., Sinclair, A. R. E., & Balmford, A. (2004). Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science*, 306, 1180–1183.
- Brashares, J. S., Golden, C. D., Weinbaum, K. Z., Barrett, C. B., & Okello, G. V. (2011). Economic and geographic drivers of wildlife consumption in rural Africa. *Proceedings of the National Academy of Sciences of the United States of America*, 108, 13931–13936.
- Bruner, A. G., Gullison, R. E., Rice, R. E., & da Fonseca, G. A. (2001). Effectiveness of parks in protecting tropical biodiversity. *Science*, 291, 125–128.
- Bulte, E. H., & Horan, R. D. (2002). Does human population growth increase wildlife harvesting? An economic assessment. *Journal of Wildlife Management*, 66, 574–580.
- Bunnefeld, N., Hoshino, E., & Milner-Gulland, E. J. (2011). Management strategy evaluation: A powerful tool for conservation? *Trends in Ecology & Evolution*, 29, 441–447.
- Campbell, K., & Hofer, H. (1995). People and wildlife: Spatial dynamics and zones of interaction. In A. R. E. Sinclair, & P. Arcese (Eds.), *Serengeti II dynamics, management, and conservation of an ecosystem* (pp. 534–570). Chicago: The University of Chicago Press.
- Ceballos, G., & Ehrlich, P. R. (2002). Mammal population losses and the extinction crisis. *Science*, 296, 904–907.
- Chaumba, J., Scones, I., & Wolmer, W. (2003). New politics, new livelihoods: Agrarian change in Zimbabwe. *Review of African Political Economy*, 30, 585–608.
- Child, B. A. (1993). Zimbabwe's CAMPFIRE programme: Using the high value of wildlife recreation to revolutionise natural resource management in communal areas. *Commonwealth Forestry Review*, 72, 284–296.
- Child, G., & Chitsike, L. (2000). "Ownership" of wildlife. In H. H. T. Prins, J. G. Grootenhuis, & T. T. Dolan (Eds.), *Wildlife conservation by sustainable use* (pp. 247–266). Norwell, MA: Kluwer Academic Publishers.
- Clerici, N., Bodini, A., Eva, H., Grégoire, J. M., Dulieu, D., & Paolini, C. (2007). Increased isolation of two Biosphere Reserves and surrounding protected areas (WAP ecological complex West Africa). *Journal for Nature Conservation*, 15, 26–40.
- Colart, D. (2008). *A decade of suffering in Zimbabwe. Development Policy Analysis*. Washington, DC: CATO Institute.
- Corlett, R. T. (2007). The impact of hunting on the mammalian fauna of tropical Asian forests. *Biotropica*, 39, 292–303.
- Cumming, D. H. M. (1999). Living off 'biodiversity': Whose land, whose resources and where? *Environment and Development Economics*, 4, 220–223.
- de Boer, W., Stigter, J., & Ntumi, C. (2007). Optimising investments from elephant tourist revenues in the Maputo Elephant Reserve, Mozambique. *Journal for Nature Conservation*, 15, 225–236.
- De Merode, E., Smith, K. H., Homewood, K., Pettifor, R., Rowcliffe, M., & Cowlishaw, G. (2007). The impact of armed conflict on protected-area efficacy in Central Africa. *Biology Letters*, 3, 299–301.
- Degeorges, A., & Reilly, B. (2007). Politicization of land reform in Zimbabwe: Impacts on wildlife, food production and the economy. *International Journal of Environmental Studies*, 64, 571–586.
- Draulans, D., & Van Krunkelsven, E. (2002). The impact of war on forest areas in the Democratic Republic of Congo. *Oryx*, 36, 35–40.
- Duffy, R. (1999). The role and limitations of state coercion: Anti-poaching policies in Zimbabwe. *Journal of Contemporary African Studies*, 17, 97–121.
- Dunham, K. M. (2002). *Aerial survey of elephants and other large herbivores in Gonarezhou National Park and some bordering lands Zimbabwe: 2001*. Harare: Department of National Parks and Wildlife Management.
- Dunham, K. M., Van Der Westhuizen, E., Van Der Westhuizen, H. F., & Gandiwa, E. (2010). *Aerial survey of elephants and other large herbivores in Gonarezhou National Park (Zimbabwe) Zinave National Park (Mozambique) and surrounds: 2009*. Harare: Zimbabwe Parks and Wildlife Management Authority.
- Emery, K. F. (2007). Assessing the impact of ancient Maya animal use. *Journal for Nature Conservation*, 15, 184–195.
- Fa, J. E., & Brown, D. (2009). Impacts of hunting on mammals in African tropical moist forests: A review and synthesis. *Mammal Review*, 39, 231–264.
- Fa, J. E., Seymour, S., Dupain, J., Amin, R., Albrechtsen, L., & Macdonald, D. (2006). Getting to grips with the magnitude of exploitation: Bushmeat in the Cross-Sanaga River region, Nigeria and Cameroon. *Biological Conservation*, 129, 497–510.
- Fusari, A., & Carpaneto, G. M. (2006). Subsistence hunting and conservation issues in the game reserve of Gile, Mozambique. *Biodiversity and Conservation*, 15, 2477–2495.
- Gandiwa, E. (2011). Preliminary assessment of illegal hunting by communities adjacent to the northern Gonarezhou National Park, Zimbabwe. *Tropical Conservation Science*, 4, 445–467.
- Gandiwa, E. (2012). Local knowledge and perceptions of animal population abundances by communities adjacent to the northern Gonarezhou National Park, Zimbabwe. *Tropical Conservation Science*, 5, 255–269.
- Gandiwa, P., Matsvayi, M., Ngwenya, M. M., & Gandiwa, E. (2011). Assessment of livestock and human settlement encroachment into northern Gonarezhou National Park, Zimbabwe. *Journal of Sustainable Development in Africa*, 13, 19–33.
- Gaston, K. J., Jackson, S. F., Cantú-Salazar, L., & Cruz-Piñón, G. (2008). The ecological performance of protected areas. *Annual Review of Ecology, Evolution, and Systematics*, 39, 93–113.
- Gibson, C. C., & Marks, S. A. (1995). Transforming rural hunters into conservationists—An assessment of community-based wildlife management programs in Africa. *World Development*, 23, 941–957.
- Golden, C. D. (2009). Bushmeat hunting and use in the Makira Forest, north-eastern Madagascar: A conservation and livelihoods issue. *Oryx*, 43, 386–392.
- Golden, C. D., Fernald, L. C. H., Brashares, J. S., Rasolofoniaina, B. J. R., & Kremen, C. (2011). Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. *Proceedings of the National Academy of Sciences*, 108, 19653–19656.
- Grey-Ross, R., Downs, C. T., & Kirkman, K. (2010). An assessment of illegal hunting on farmland in KwaZulu-Natal, South Africa: Implications for Oribi (*Ourebia ourebi*) conservation. *South African Journal of Wildlife Research*, 40, 43–52.
- Hanke, S. H., & Kwok, A. K. F. (2009). On the measurement of Zimbabwe's Hyperinflation. *Cato Journal*, 29, 353–364.
- Hardin, G. (1968). The tragedy of the commons. *Science*, 162, 1243–1248.

- Harrison, R. D. (2011). Emptying the Forest: Hunting and the Extirpation of Wildlife from Tropical Nature Reserves. *BioScience*, 61, 919–924.
- Hayward, M. W. (2009). Bushmeat hunting in Dwesa and Cwebe Nature Reserves, Eastern Cape, South Africa. *South African Journal of Wildlife Research*, 39, 70–84.
- Hofer, H., Campbell, K. L. I., East, M. L., & Huish, S. A. (2000). Modeling the spatial distribution of the economic costs and benefits of illegal game meat hunting in the Serengeti. *Natural Resource Modeling*, 13, 151–177.
- Holland, M. B. (2012). The role of protected areas for conserving biodiversity and reducing poverty. In J. C. Ingram, F. DeClerck, & C. R. del Rio (Eds.), *Integrating ecology and poverty reduction: The application of ecology in development solutions* (pp. 253–272). New York: Springer.
- Holmern, T., Mkama, S., Muya, J., & Røskræft, E. (2006). Intraspecific prey choice of bushmeat hunters outside the Serengeti National Park, Tanzania: A preliminary analysis. *African Zoology*, 41, 81–87.
- Holmern, T., Muya, J., & Røskræft, E. (2007). Local law enforcement and illegal bushmeat hunting outside the Serengeti National Park, Tanzania. *Environmental Conservation*, 34, 55–63.
- Hurt, R., & Ravn, P. (2000). Hunting and its benefits: An overview of hunting in Africa with special reference to Tanzania. In H. H. T. Prins, J. G. Grootenhuis, & T. T. Dolan (Eds.), *Wildlife conservation by sustainable use* (pp. 295–314). Boston, MA: Kluwer Academic Publishers.
- IUCN (2012). *IUCN Red List of Threatened Species. Version 2012.1*. <www.iucnredlist.org>. Downloaded on 15 August 2012.
- Jachmann, H. (2008a). Illegal wildlife use and protected area management in Ghana. *Biological Conservation*, 141, 1906–1918.
- Jachmann, H. (2008b). Monitoring law-enforcement performance in nine protected areas in Ghana. *Biological Conservation*, 141, 89–99.
- Jachmann, H., & Billiouw, M. (1997). Elephant poaching and law enforcement in the central Luangwa Valley, Zambia. *Journal of Applied Ecology*, 34, 233–244.
- Jachmann, H., Blanc, J., Nateg, C., Balangtaa, C., Debrah, E., Damma, F., et al. (2011). Protected area performance and tourism in Ghana. *South African Journal of Wildlife Research*, 41, 95–109.
- Jenkins, R. K. B., Keane, A., Rakotoarivel, A. R., Rakotomboavonjy, V., Randrianandriana, F. H., Razafimanahaka, H. J., et al. (2011). Analysis of patterns of bushmeat consumption reveals extensive exploitation of protected species in eastern Madagascar. *PLoS One*, 6, e27570, doi:10.1371/journal.pone.0027570
- Johannesen, A. B. (2006). Designing integrated conservation and development projects (ICDPs): Illegal hunting, wildlife conservation, and the welfare of the local people. *Environment and Development Economics*, 11, 247–267.
- Kaltenborn, B., Nyahongo, J., Kidegesho, J., & Haaland, H. (2008). Serengeti National Park and its neighbours—Do they interact? *Journal for Nature Conservation*, 16, 96–108.
- Kanyamibwa, S. (1998). Impact of war on conservation: Rwandan environment and wildlife in agony. *Biodiversity and Conservation*, 7, 1399–1406.
- Karp, D. R., & Gaulding, C. L. (1995). Motivational underpinnings of command-and-control, market-based, and voluntarist environmental policies. *Human Relations*, 48, 439–465.
- Keane, A., Jones, J. P. G., Edwards-Jones, G., & Milner-Gulland, E. J. (2008). The sleeping policeman: Understanding issues of enforcement and compliance in conservation. *Animal Conservation*, 11, 75–82.
- Koch, P. L., & Barnosky, A. D. (2006). Late quaternary extinctions: State of the debate. *Annual Review of Ecology, Evolution, and Systematics*, 37, 215–250.
- Kümpel, N. F., Milner-Gulland, E., Rowcliffe, J. M., & Cowlishaw, G. (2008). Impact of gun-hunting on diurnal primates in continental Equatorial Guinea. *International Journal of Primatology*, 29, 1065–1082.
- Kümpel, N. F., Milner-Gulland, E. J., Cowlishaw, G., & Rowcliffe, J. M. (2010). Incentives for hunting: The role of bushmeat in the household economy in rural Equatorial Guinea. *Human Ecology*, 38, 251–264.
- Laurance, W. F., Croes, B. M., Guissouegou, N., Buij, R., Dethier, M., & Alonso, A. (2008). Impacts of roads, hunting, and habitat alteration on nocturnal mammals in African rainforests. *Conservation Biology*, 22, 721–732.
- Leader-Williams, N., Albon, S. D., & Berry, P. S. M. (1990). Illegal exploitation of black rhinoceros and elephant populations: Patterns of decline, law enforcement and patrol effort in Luangwa Valley, Zambia. *Journal of Applied Ecology*, 27, 1055–1087.
- Leeuwis, C., & van den Ban, A. (2004). *Communication for rural innovation: Rethinking agricultural extension*. Oxford: Blackwell Publishing.
- Lindsey, P. A., du Toit, R., Pole, A., & Romañach, S. (2009). Savé valley conservancy: A large scale African experiment in cooperative wildlife management. In H. Suich, B. Child, & A. Spenceley (Eds.), *Evolution and innovation in wildlife conservation from parks and game ranches to transfrontier conservation areas* (pp. 163–184). London: Earthscan.
- Lindsey, P. A., Romañach, S. S., Tambling, C. J., Chartier, K., & Groom, R. (2011). Ecological and financial impacts of illegal bushmeat trade in Zimbabwe. *Oryx*, 45, 96–111.
- Ling, S., & Milner-Gulland, E. J. (2006). Assessment of the sustainability of bushmeat hunting based on dynamic bioeconomic models. *Conservation Biology*, 20, 1294–1299.
- Loibooki, M., Hofer, H., Campbell, K. L. I., & East, M. L. (2002). Bushmeat hunting by communities adjacent to the Serengeti National Park, Tanzania: The importance of livestock ownership and alternative sources of protein and income. *Environmental Conservation*, 29, 391–398.
- MacKenzie, C. A. (2012). Trenches like fences make good neighbours: Revenue sharing around Kibale National Park, Uganda. *Journal for Nature Conservation*, 20, 92–100.
- Makina, D. (2012). Migration and Characteristics of Remittance Senders in South Africa. *International Migration*, doi:10.1111/j.1468-2435.2012.00746.x.
- Mapedza, E., & Bond, I. (2006). Political deadlock and devolved wildlife management in Zimbabwe: The case of Nenyunga ward. *The Journal of Environment & Development*, 15, 407–427.
- Martin, E. (2010). Effective law enforcement in Ghana reduces elephant poaching and illegal ivory trade. *Pachyderm*, 48, 24–32.
- Metzger, K. L., Sinclair, A. R. E., Hilborn, R., Hopcraft, J. G. C., & Mduma, S. A. R. (2010). Evaluating the protection of wildlife in parks: The case of African buffalo in Serengeti. *Biodiversity and Conservation*, 19, 3431–3444.
- Milner-Gulland, E., & Akçakaya, H. R. (2001). Sustainability indices for exploited populations. *Trends in Ecology & Evolution*, 16, 686–692.
- Milner-Gulland, E., Bennett, E. L., & the SCB 2002 Annual Meeting Wild Meat Group. (2003). Wild meat: The bigger picture. *Trends in Ecology & Evolution*, 18, 351–357.
- Mombeshora, S., & Le Bel, S. (2009). Parks-people conflicts: The case of Gonarezhou National Park and the Chitsa community in south-east Zimbabwe. *Biodiversity and Conservation*, 18, 2601–2623.
- Moyle, B. (2009). The black market in China for tiger products. *Global Crime*, 10, 124–143.
- Mtsambwi, M. Z. (2003). *Transforming protected areas system management during turbulent times—The Zimbabwean experience* 5th World Parks Congress,. Durban: IUCN (World Conservation Union).
- Murphree, M. W. (1988). *Decentralising the proprietorship of wildlife resources in Zimbabwe's communal lands: An outline of the central issues*. Harare: Centre of Applied Social Sciences, University of Zimbabwe.
- Naughton-Treves, L., Holland, M. B., & Brandon, K. (2005). The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annual Review of Environment and Resources*, 30, 219–252.
- Newmark, W. D. (2008). Isolation of African protected areas. *Frontiers in Ecology and the Environment*, 6, 321–328.
- Noss, A. J. (1998). The impacts of cable snare hunting on wildlife populations in the forests of the Central African Republic. *Conservation Biology*, 12, 390–398.
- Nyahongo, J., Holmern, T., Kaltenborn, B. P., & Røskræft, E. (2009). Spatial and temporal variation in meat and fish consumption among people in the western Serengeti, Tanzania: The importance of migratory herbivores. *Oryx*, 43, 258–266.
- Nyahongo, J. W., East, M. L., Mturi, F. A., & Hofer, H. (2005). Benefits and costs of illegal grazing and hunting in the Serengeti ecosystem. *Environmental Conservation*, 32, 326–332.
- Ogutu, J. O., Owen-Smith, N., Piepho, H. P., & Said, M. Y. (2011). Continuing wildlife population declines and range contraction in the Mara region of Kenya during 1977–2009. *Journal of Zoology*, 285, 99–109.
- Ostrom, E. (2010). A multi-scale approach to coping with climate change and other collective action problems. *Solutions*, 1, 27–36.
- Parr, J. (2011). Illegal wildlife trade: A need for institutional mapping—A response to Bennett. *Oryx*, 45, 480–481.
- Paudel, P. K., & Kindermann, P. (2012). Distribution pattern of the threatened Himalayan serow (*Capricornis thar*) in western midhills of Nepal: An insight for conservation along an altitudinal gradient. *Journal for Nature Conservation*, 20, 177–180.
- Peres, C. A. (2000). Effects of subsistence hunting on vertebrate community structure in Amazonian Forests. *Conservation Biology*, 14, 240–253.
- Peres, C. A. (2001). Synergistic effects of subsistence hunting and habitat fragmentation on Amazonian forest vertebrates. *Conservation Biology*, 15, 1490–1505.
- Pires, S. F., & Moreto, W. D. (2011). Preventing wildlife crimes: Solutions that can overcome the 'Tragedy of the Commons'. *European Journal on Criminal Policy and Research*, 17, 101–123.
- Rao, M., Myint, T., Zaw, T., & Htun, S. (2005). Hunting patterns in tropical forests adjoining the Hkakaborazi National Park, north Myanmar. *Oryx*, 39, 292–300.
- Robinson, J. G., & Bennett, E. L. (2004). Having your wildlife and eating it too: An analysis of hunting sustainability across tropical ecosystems. *Animal Conservation*, 7, 397–408.
- Rowcliffe, J. M., de Merode, E., & Cowlishaw, G. (2004). Do wildlife laws work? Species protection and the application of a prey choice model to poaching decisions. *Proceedings of the Royal Society, London, B*, 271, 2631–2636.
- Sibanda, B. (1995). Wildlife, conservation and the Tonga in Omay. *Land Use Policy*, 12, 69–85.
- Singh, S. P., & Sharma, C. M. (2009). Tropical ecology: An overview. *Tropical Ecology*, 50, 7–21.
- The Guardian (2008). *Mugabe presides over decline in Zimbabwe's wildlife parks*. <<http://www.guardian.co.uk/environment/2008/may/30/conservation.wildlife>>. Accessed 24.05.12.
- Tumusime, D. M., Etilu, G., Tweheyo, M., & Babweteera, F. (2010). Wildlife snaring in Budongo Forest Reserve Uganda. *Human Dimensions of Wildlife*, 15, 129–144.
- Uddin, M. A., & Foisel, A. S. A. (2007). Local perceptions of natural resource conservation in Chunita Wildlife Sanctuary. In J. Fox, B. R. Bushley, S. Dutt, & S. A. Quazi (Eds.), *Making conservation work: Linking rural livelihoods and protected area management in Bangladesh* (pp. 84–109). Bangladesh: East-West Center and Nishorgo Program of the Bangladesh Forest Department.
- Van der Hoeven, C. A. (2007). *The missing link, bridging the gap between science and conservation*. PhD Thesis. Wageningen, The Netherlands: Wageningen University.
- Wato, Y. A., Wahungu, G. M., & Okello, M. M. (2006). Correlates of wildlife snaring patterns in Tsavo West National Park, Kenya. *Biological Conservation*, 132, 500–509.
- Wels, H. (2003). *Private wildlife conservation in Zimbabwe: Joint ventures and reciprocity*. Leiden: Brill.

- Wilfred, P., & MacColl, A. D. C. (2010). Income sources and their relation to wildlife poaching in Ugalla ecosystem, Western Tanzania. *African Journal of Environmental Science and Technology*, 4, 886–896.
- Wilkie, D. S., Bennett, E. L., Peres, C. A., & Cunningham, A. A. (2011). The empty forest revisited. *Annals of the New York Academy of Sciences*, 1223, 120–128.
- Wilkie, D. S., & Carpenter, J. F. (1999). Bushmeat hunting in the Congo basin: An assessment of impacts and options for mitigation. *Biodiversity and Conservation*, 8, 927–955.
- Williams, S. T. (2011). *The impact of land reform in Zimbabwe on the conservation of cheetahs and other large carnivores*. PhD Thesis. Durham, United Kingdom: Durham University.
- Wolmer, W. (2005). Wilderness gained, wilderness lost: Wildlife management and land occupations in Zimbabwe's southeast lowveld. *Journal of Historical Geography*, 31, 260–280.
- Yamagiwa, J. (2003). Bushmeat poaching and the conservation crisis in Kahuzi-Biega National Park, Democratic Republic of the Congo. *Journal of Sustainable Forestry*, 16, 111–130.