Crop raiding by wildlife on subsistence homesteads around the Hluhluwe Game Reserve, South Africa

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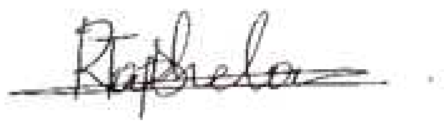
DECLARATION

I declare that the research work reported in this thesis is my own, unaided work except where otherwise indicated and acknowledged. It is submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. This thesis has not, either in whole or in part, been submitted for any degree at any other university.



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ABSTRACT

The literature on human-wildlife conflict shows that subsistence farming is a neglected area of research in South Africa. Instead the focus has been on the interaction between wildlife and commercial farmers, in particular livestock losses because of carnivore attacks. Studies of crop losses to wildlife in subsistence farming are lacking. The aim of my study was therefore to investigate the impact of crop raiding by wildlife, particularly rodents and primates, on subsistence farmers on the edge of the Hluhluwe Game Reserve, in the northern KwaZulu-Natal Province, South Africa. The main hypothesis was that crop raiding by wildlife would impact the livelihood and lives of subsistence farmers and compromise their food security. I first investigated the seasonal variation in crop raiding behaviour by measuring the level of damage, identifying the crop raiding animal groups and the crop types frequently raided. The highest level of crop damage was during the dry season, caused by rodents, birds and insects. Maize (*Zea mays*) suffered the highest level of damage. Interestingly, primates in the Hluhluwe Game Reserve never transgressed the farm boundaries to raid crops, but were observed feeding more than travelling next to the farms. I next investigated the nutritional and economic impact of crop raiding on subsistence farmers seasonally. Again, the highest nutritional and economic impact of crop raiding was during the dry season and the highest nutritional loss was recorded for maize overall; the annual potential income loss was about R2 427/annum (about US$180.71). Next, I investigated the opinions and perceptions of subsistence farmers on crop raiding and the control measures employed by farmers to deter crop-raiding animals. Farmers differed in their opinions and perceptions to crop raiding in relation to their proximity to the reserve boundary; farmers closer to the reserve viewed wildlife as pests more than farmers further away from the reserve. Several candidate crop raiders were identified, and there were positive correlations between the levels of control measures employed by farmers and factors known to influence crop raiding by wildlife (i.e. distance of farms from the reserve, crop raiding animals and crop types raided). Subsequently, I investigated the opinions and perceptions of conservation practitioners on crop raiding and issues related to crop raiding by wildlife of surrounding subsistence farmers. I also assessed the implementation of community outreach programmes by the Hluhluwe Game Reserve management. Conservationists produced mixed responses and contradictions when asked about which animals: i) raided crops on adjacent farms; ii) were reported to raid crops by the neighbouring communities; and iii) escaped from the reserve. Overall, most conservationists reported that the reserve had not implemented community outreach programmes. By combining data from previous chapters, I assessed the effects of crop raiding on food security of subsistence homesteads; homestead dietary diversity was used as a proxy for food security. I found indicators of crop raiding by wildlife impacting the food security of these homesteads, particularly on small farms and larger homesteads. My study revealed that subsistence farmers are affected by wildlife but not to the extent anticipated. Some but not all the usual wildlife raiders were identified by this study. Farmers responded to crop raiding by using specific deterrents. Crop raiding appears to influence food security of the farmers, but its actual impact requires further study.

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General Introduction

Human-wildlife conflict occurs when wild animals depredate crops and livestock and threatens human safety, which subsequently results in deliberate retaliation by farmers (Woodroffe *et al*., 2005). Human-wildlife conflicts have been reported worldwide by many studies (Hill, 1997; Kolowski & Holekamp, 2006; Seoraj-Pillai & Pillay, 2016; Wielgus & Peebles, 2014; Zhang & Wang, 2003). For example, in America, large numbers of cattle (*Bos primigenius*) and sheep (*Ovis aries*) were depredated by gray wolves (*Canis lupus*) between 1987 and 2012, causing conflict between the livestock owners and the conservation authorities over the conservation of the wolves (Wielgus & Peebles, 2014). In the Simao region of Yunnan Province, China, the impact of the Asian elephant (*Elephas maximus*) on the rural agricultural economy from 1996 to 2000 caused serious human–elephant conflict in the region; elephants were responsible for large-scale crop and property damage in the region (Zhang & Wang, 2003).

In Africa, several incidences of human-wildlife conflict have been reported in the literature. Hill (1997) reported chacma baboon (*Papio ursinus*) as the leading crop raider in Western Uganda, especially for maize (*Zea mays*). Crop raiding by bush pig (*Potamochoerus larvatus*) were also reported to be the cause of human-wildlife conflict in Uganda (Hill, 1997). In Kenya, adjacent to the Maasai Mara National Reserve, spotted hyena (*Crocuta crocuta*), leopard (*Panthera pardus*) and lion (*Panthera leo*) were responsible for 53%, 32%, and 15% of attacks on livestock (mostly cattle; *Bos taurus*) respectively (Kolowski & Holmen, 2006). In South Africa, black-backed jackal (*Canis mesomelas*) and caracal (*Caracal caracal*) were most often implicated in livestock predation (Thorn *et al*., 2012).

Worldwide the retaliatory and deliberate killings of wild animals are underpinned by negative attitudes and opinions of people towards perceived damage caused by animals (i.e. attacks on livestock, crops and/or people; Seoraj-Pillai, 2016). Lindsey *et al*. (2005) and Olsen *et al*. (2014) reported active persecution of wild animals, ranging from sporadic poisoning to government-driven extirpations as high on the list of retaliatory measures worldwide. Wielgus & Peebles (2014) reported a number of wolves killed by livestock owners in China. Moreover, depredation of crops, livestock and also attacks on humans by the Asiatic black bear (*Ursus thibetanus*) in China apparently resulted in increased bear poaching (Liu *et al*., 2011).

Livestock losses because of wildlife depredation are often the focus of research studies (Peterson *et al*., 2010; Sitati *et al*., 2005). In contrast, crop raiding by wildlife is sometimes overlooked even though it is reported to be a major cause of human–wildlife conflict worldwide (Sillero–Zubiri & Switzer 2001; Linkie *et al*., 2007). Hazell (2003) added that trampling by some animals (e.g. elephant *Loxodonta africana*) should also be regarded as crop raiding, since crops are damaged in the process. Crop raiding by wildlife may cause substantial damage to agricultural crops (Hill, 2000; Naughton-Treves *et al*., 2007), yet a perfect long-term solution is lacking (Wallace & Hill, 2012). A variety of crops, such as cereal and fruit, are targeted by animals (Bariregа *et al*., 2010; Hill *et al*., 2002; Mwakatobe *et al*., 2014), but crops that are mostly destroyed (or perhaps more frequently reported) during raiding include maize (*Zea mays*), sweet potato (*Ipomea batatas*), tobacco (*Nicotiana tabacum*), beans (*Phaseolus vulgalis*), ground nuts (*Arachis hypogaea*), and sugar cane (*Saccarum africanum*) (Treves *et al*., 2006). The damage can be substantial, ranging, for example, from about 50% for wheat to more than 80% for sugarcane of the cultivated land (Oerke, 2006).

Through crop raiding, wildlife can impact local livelihoods and undermine conservation efforts, particularly in developing countries (Naughton-Treves, 1999). In Africa, crop raiding by wildlife is often common on farms on the edges of protected areas (e.g. nature reserves), leading to conflict between farmers and conservation practitioners (Hill, 1997). Effective long-term solutions to this problem might assist in other problems, such as food shortages in rural communities that are dependent on crops they grow and store for staple food (Sitati *et al*., 2005). Archibald & Naughton-Treves (2001) reported that crop raiding by wildlife is the most important reported disadvantage of farming close to protected areas in Africa. Thus, understanding crop raiding should include the impact of crop raiding on people's livelihoods and food security (Seoraj-Pillai, 2016; Sillero-Zubiri & Switzer, 2001). Not only is such knowledge vital to mitigate the effects of crop raiding but also to reduce human-wildlife conflict (Baker *et al*., 2005, 2007; Nyhus *et al*., 2005).

Even though human-wildlife conflict has been studied in many parts of Africa (Bukie *et al*., 2018; Hill, 2000, 2002; Naughton-Treves, 1997, 1998; Mwakatobe *et al*., 2014), the crop raiding behaviour of wildlife in South Africa is not well reported (Infield 1986, 1988; Seoraj-Pillai & Pillay, 2016). This is particularly the case for subsistence farmers possibly because incidences of crop raiding in South Africa are isolated and thus often unpublished (Hough, 1988; Thouless & Sakwa, 1995; Tchamba, 1996).

Crop raiding animals

The increasing human population and movement of people closer to areas with wildlife, especially in the developing world, is likely the underlying reason for the increase in crop raiding by wildlife (Bukie *et al*., 2018; Marchal & Hill, 2009). With humans and wildlife living in ever-closer proximity, an in-depth understanding and knowledge of crop raiding is needed. This understanding should include interspecific differences in patterns of crop raiding by wildlife, ways to predict future crop-raiding events, and understanding of the behaviour of crop raiding animals. There are many examples of crop raiding behaviour of wildlife globally, involving many species. Examples include African elephant (*Loxodonta africana*) and Asian elephant in Africa and Asia respectively, wild boar (*Sus scrofa*) in eastern Europe, white-tailed deer (*Odocoileus virginianus*) in America and many insects, rodents and bird species worldwide (Sillero-Zubiri & Laurenson, 2001). Generally, foraging on agricultural land has been found to increase growth and reproduction of animal species due to increased foraging efficiency and greater food quality (i.e. energy available) and quantity (Sillero–Zubiri & Switzer 2001). At the same time, raiding can lead to their death due to retaliation from farmers (Graham-Rowe, 2011).

The main species that raid agricultural land in Africa are reported to be elephants (*Loxodonta africana*), crested porcupines (*Hystrix aficaeaustralis*), primates such as baboons (*Papio* spp), redtail monkeys (*Cercopithecus ascanius*), vervet monkeys (*Chlorocebus pygerythrus*), chimpanzees (*Pan troglodytes*), bushpig (*Potamochoerus* sp.) and antelope species, such as red duiker (*Cephalophus* sp.) and bushbuck (*Tragelaphus scriptus*) (Naughton-Treves, 1997; Naughton-Treves *et al*., 1998; Priston, 2001). Some of the more dramatic cases like swarms of locusts that devastate large swaths of crops in many parts of the world, tend to receive wide coverage in the media (Sillero-Zubiri & Laurenson, 2001). However, crop raiding by vertebrates, such as birds and mammals, is also a major concern (Sillero-Zubiri & Switzer, 2001) and often underreported in the scientific literature. For example, in the Lake Chad region of Nigeria, quelea (*Quelea quelea*) caused extensive damage to crops of dry–season guinea-corn, and quelea were also reported to feed on ripening grass seeds including those of cultivated millet (*Pennisetum glaucum*; Ward 2006).

In Africa, multimammate mice (*Mastomys natalensis*) are a major tropical crop pest (Hill, 2008). In Tanzania, multimammate mice were found feeding on crops during the dry season (Leirs *et al*., 1994). Given this wide diversity of crop raiders, it is necessary to identify crop-raiding species and their patterns of crop raiding in order to identify the most effective mitigation strategies based on their unique crop raiding behaviour (Linkie *et al*., 2007).

Impact of crop raiding

Globally, crop raiding by wildlife impacts the lives and livelihoods of farmers (Studsrod & Wegge, 1995; Desoky, 2015), including subsistence farmers (Nchanji & Lawson, 1998). These farmers face substantial challenges that undermine food production, subsequently reducing their required daily nutritional intake and potential income (Ndaeyo, 2007; Nyamwamu *et al.*, 2015). For example, in the United States of America, Pimentel *et al.* (2000) found that rodents caused economic damage to stored grains, with a total cost of destruction of approximately US$4 billion per annum across the country.

In Africa, the estimated costs of crop raiding have been reported in some studies and gaining attention in the literature (Khan, 1994, DeGeorges & Reilly, 2008, Mwakatobe *et al.*, 2014). For example, on the forest edge of Entebbe, Uganda, several farmers suffered financial losses due to vervet monkey crop-raiding, amounting to US$80 to US$400 per annum (Saj *et al*., 1998). Little is known about how rural South African subsistence homesteads, the most economically vulnerable groups of people, are affected by crop raiding (Seoraj-Pillai, 2016). Hill (2000) reported that crop raiding could make already insecure livelihoods even more marginal in economic terms.

Studies of socio-economic impacts of crop raiders on subsistence farmers are relatively rare, and thus attempt to manage “problem” animals need to be carried out by investigating the experiences of each farmer (Mackenzie & Ahoyona, 2012). Crop raiding has long been known to severely affect farmers on the edge of protected areas, often resulting in a reduction of food supply in subsistence homesteads (Bukie *et al*., 2018) and thus a reduction in their daily nutrients (Baririega *et al*., 2010; Nyirenda *et al*., 2013). Undernutrition levels of people are reported to be higher near biodiversity hotspots than for the country as a whole (Scherr & McNeely, 2001), perhaps because of crop losses. Ultimately, reduction in food supply could even result in starvation in many subsistence homesteads (Kaswamila *et al*., 2007). Wildlife crop damage not only negatively impacts food supply but also livelihood security of rural subsistence communities, through potential income loss that could offset crop loss. Therefore, the investigation of human-wildlife conflict on subsistence farmers should consider nutritional and economic losses of people because these are the key variables in addressing food security in rural subsistence farming (Barirega *et al*., 2010; Mackenzie & Ahoyona, 2012).

Perceptions, opinions and views of farmers and conservationists

Negative perceptions and opinions of people towards perceived damage caused by animals often leads to the deliberate killing of wildlife (Alexander *et al*., 2015; Anthony, 2007). Therefore, future conservation efforts depend on understanding and considering the perceptions and opinions of people towards wildlife crop raiding behaviour and levels of damage, especially those of rural subsistence farmers, whose opinions are often neglected (Lindsey *et al*., 2005; Olsen *et al*., 2014). However, the factors affecting people's perception and opinions towards wildlife crop raiding are difficult to quantify and investigate (Kellert, 1993). For example, in Zambia, Nyirenda *et al*. (2013) reported differences in perceived and actual crop losses for maize (*Zea mays*) and cotton (*Gossypium arboreum*) of 49.49% and 7.78%, respectively, for mono-specific stands of maize and cotton. Costs perceived by local farmers were higher than the actual loss (Nyireda *et al*., 2013). In addition, the opportunity costs mentioned by local farmers were higher than direct costs; most farmers (79.83%) associated opportunity costs of wildlife crop damage with loss of sleep and time for other chores, when providing crop protection (Nyirenda *et al*., 2013).

Wallace & Hill (2012) reported that farmers' perception of the most destructive wildlife species is often nuanced by factors other than damage to crops or livestock. In agreement, Siex & Struhsaker (1999) reported that the association of wildlife with damage is embedded in the minds of local human communities. In a recent study in South Africa, Seoraj-Pillai (2016) reported that farmers' opinions about damage causing animals varied depending on individual experiences, values and beliefs. Negative opinions about damage causing animals were related to free-ranging wildlife and stray animals in addition to the lack of communication with conservation authorities (Seoraj-Pillai, 2016). Therefore, reducing the deliberate wildlife killings by people following raiding lies in assessing the opinions and views of farmers (Anthony 2007). Nyirenda *et al*. (2013) reported that wildlife conservation in Luangwa Valley, Zambia, depended on the perceptions of local communities, and was affected by wildlife crop raiding. The ensuing negative perception appeared to pose high risks to wildlife conservation in Luangwa Valley (Nyirenda *et al*., 2013).

Limited research is available about how people who manage protected areas perceive crop raiding of wildlife, but instead human-wildlife studies concentrate on farmers' opinions and perceptions (Marker *et al*., 2003; Schumann *et al*., 2008; Thorn *et al*., 2012). My literature search revealed a single study in northeastern South Africa that compared the attitudes and opinions of conservation practitioners as well as local human communities towards wildlife and human-wildlife conflict (Seoraj-Pillai, 2016). Conservation practitioners in different provinces in South Africa had similar negative opinions and perceptions to farmers' retaliation to crop raiding, maintaining positive responses towards wildlife (Seoraj-Pillai, 2016). Seoraj-Pillai (2016) also reported tensions between farmers (subsistence and commercial) and conservationists, even though there were positive attitudes and opinions of biodiversity by these farmers and reported willingness of conservationists for community conservation.

It is therefore imperative to assess whether the conservation practitioners' opinions and perceptions about crop raiding are applicable globally (DeGeorge & Reilly, 2008; Woodroffe *et al*., 2005). Differences in opinions and perceptions about damage causing animals between farmers and conservation practitioners are in most cases "the breeding ground" for conflict (Dickman, 2010). Jackson & Wangchuk (2001)) reported that documenting the opinions and perceptions of farmers and conservationists is a necessary first step in the mitigation of human-wildlife conflict.

Food security

Crop raiding disrupts livelihoods (Barirega *et al*., 2010). In Africa, crop raiding, leaves communities vulnerable to food insecurity, contributing to starvation (Deng *et al*., 2009; Mwakatobe *et al*., 2014; Seoraj-Pillai, 2016). For example, in Uganda, adjacent to Queen Elizabeth Park, crop raiding dominated by elephants resulted in 14% annual reduction in homestead food security of adjacent human communities (Barirega *et al*., 2010). Again, in Uganda, the crop raiding by wild animals from Bugoma forest reserve left the subsistence farmers more vulnerable to food insecurity than before crop raiding (Joseline, 2010). The strong link between crop raiding and food insecurity in subsistence farmers (Warren, 2003) means that farmers have to find ways to secure their food supply from planting until production and storage.

The notion of food security is not new, but the manner in which it has been conceptualised has been changing with emerging research to include the extent of the damage caused by crop raiders (Baiphethi & Jacobs, 2009). In addition to the loss of food, crop raiding is also reported as one of the major threats to rural incomes (Dupont & Thirlwell, 2009), which can offset food loss and increase the opportunity for purchasing deterrents (e.g. pesticides) against crop raiders (Berkenkamp, 2006). Little is written about the difficulty experienced by subsistence farmers between planting and harvest in relation to crop pests (Jacobs *et al*., 2009), even though rural community farms are suggested to promote food security (Jacobs *et al*., 2009). Moreover, little is known about crop raiding species, the damage they cause and the extent to which these pests can exacerbate food insecurity in subsistence farming communities (Mackenzie & Ahabyona, 2012). Effective long-term solutions to mitigate crop raiding might assist in several problems facing rural communities that are dependent on crops they grow and store (Sitati *et al*., 2005).

Rationale for the study

Human-wildlife conflict has been extensively investigated worldwide (Hill, 2000; Naughton-Treves, 1999). However, I am not aware of any study that has explicitly investigated crop raiding by wildlife as one form of human-wildlife conflict that directly affects rural subsistence farmers, particularly in South Africa. Furthermore, studies that investigated human-wildlife conflict in South Africa have used mostly questionnaire surveys (Infield, 1986, 1988) when a combination of methods (e.g. a field surveys and questionnaires) is often necessary for a comprehensive assessment of the extent of crop raiding.

A literature search shows that, in South Africa, a country rich in agricultural resources and where rural communities live off food gardens (Altman *et al*., 2009), subsistence farming is a neglected area of scientific research. Yet, several studies have examined the interactions between wildlife and commercial farmers (Hazell, 2003; Govereh & Jayne, 2003; Seoraj-Pillai & Pillay, 2016). Moreover, a number of studies have focused on damage caused by carnivores to livestock, in which the damage is largely quantified (Naughton-Treves *et al*., 1998; Holmen *et al*., 2007; Wang & MacDonald, 2006). For example, Holmen *et al*. (2007) reported livestock depredation by spotted hyena (*Crocuta crocuta*) outside the Serengeti National Park in Tanzania. In villages around Jigme Singye Wangchuck National Park, central Bhutan, Wang & MacDonald (2006) report livestock depredation by wild carnivores including leopard (*Panthera pardus*), tiger (*Panthera tigris*), Himalayan black bear (*Ursus thibetanus*), and the dhole (*Cuon alpinus*). In South Africa, in the North West Province, black-backed jackals (*Canis mesomelas*) and caracal were most often implicated in livestock predation.

Crop raiding by wildlife is often overlooked and the degree of damage that these animals cause to subsistence homesteads is not properly quantified (Kaswamila *et al*., 2007). An important issue is how the lives of the people are affected by crop raiding and how wildlife is impacted consequently or even concurrently. Not only is subsistence farmers' livelihoods impacted negatively by crop raiding (Barirega *et al*., 2010; Kaswamila *et al*., 2007), the conservation of wildlife is affected by retaliation (Bulte & Rodeau, 2015). Thus, mutually supportive relationships between communities and conservationists of nearby protected areas are critical to the long-term success of conservation efforts and food security in local communities (Barirega *et al*., 2010).

My study considered crop loss in a South African subsistence community as a result of wildlife damage and how wildlife is influencing food security through potential nutritional and income loss by farmers. Crops form an important part of the diet for most rural people in South Africa. For example, maize (*Zea mays*) alone, promoted as a food security crop by the South African government, is a staple food crop for about 85% of the subsistence community (Infield, 1988; StatsSA report, 2011). My study is novel since I quantified loss unlike most human-wildlife conflict studies: I quantified the level of crop damage caused to different crops by wildlife by taking direct measures; and I investigated the nutritional losses suffered by these farmers by quantifying energy loss using laboratory analyses. In addition, I gathered the opinions and perceptions of farmers and conservationists about human-wildlife conflict in the farming community to assess potential areas of conflict between farmers and conservationists to enable future mitigation of such conflict.

Aims, objectives and hypothesis

My study was concerned with assessing the crop raiding of wildlife on rural subsistence farmers of the Phindisweni community. Focusing on this community allowed me to conduct intensive field and later laboratory work on the crop losses in this community. My study comprises of five analytical chapters, with five objectives. 1. To quantify the extent of crop raiding by wildlife (Chapter 2). This study was carried out by sampling small mammals using live trapping and camera trap footage of larger mammals and through direct observations. This chapter describes factors affecting the susceptibility of farms to crop raiding by wildlife. 2. To quantify the seasonal variation in pre and post harvest energy and economic loss to farmers because of crop raiding, using field sampling and laboratory analyses (Chapter 3). This chapter considers the hidden dimensions of crop raiding to farmers. 3. To ascertain subsistence farmers' perceptions and opinions to crop raiding and to quantify their mitigation, using questionnaire surveys (Chapter 4). 4. To gauge the views of conservation practitioners on crop raiding and issues related to crop raiding, using questionnaire surveys (Chapter 5). 5. To assess food security of the farmers by analysing the data collected in the other chapters (Chapter 6). The main hypothesis is that crop raiding by wildlife will impact the livelihood and lives of subsistence farmers and compromise their food security.

Study Site

The study was conducted in Phindisweni rural community (28°03' S; 31° 23''E), located adjacent to the Hluhluwe Game Reserve (28°00' S; 31° 43''E), in the northern KwaZulu-Natal Province, South Africa. This reserve lies in the foothills of the South African escarpment and to the west of a coastal plain (Whateley & Porter, 1983; Bond *et al*., 2001). The reserve covers an area of approximately 300 km^2 (Murray, 1982; MacDonald 1983; Tarrant, 2012). Like most protected areas in South Africa, the Hluhluwe Game Reserve boundaries are surrounded with electric fences.

The numerous hills and valleys in this reserve have altitudes ranging from 60 m to 750 m above mean sea level (Whateley & Porter, 1983; Cromsigt *et al*., 2017). The mean annual rainfall ranges from 650 to 985 mm in the area, falling mainly between October and March (Owen-Smith, 1989). The predominant vegetation type in the reserve is savanna woodland (Te Beeste *et al*., 2012).

The Hluhluwe Game reserve was established because of concerns about the disappearance of wildlife as a result of hunting in the region (previously known as Zululand), especially of the white rhinoceros (*Ceratotherium simum*; Milner-Gulland, 2001; Makhabu *et al*., 2006). The Hluhluwe Game Reserve has a high faunal diversity, which includes megaherbivores such as rhinoceros (*Rhinocerotidae*), elephants (*Loxodonta africana*) and a wide spectrum of other herbivores, such as nyala (*Tragelaphus angasii*), springbok (*Antidorcas marsupialis*) and wildebeest (*Connochaetes* spp), buffalo (*Syncerus caffer*), zebra (*Equus quagga*), warthog (*Phacochoerrus africanus*), waterbuck (*Kobus* *ellipsiprymnus*), giraffe (*Giraffa camelopardalis*), kudu (*Tragelaphus strepsiceros*), impala (*Aepyceros melampus*), hippopotamus (*Hippopotamus amphibius*). In addition, there are primates, such as the vervet monkey (*Chlorocebus pygerythrus*) and chacma baboon (*Papio ursinus*) and various small mammals and birds (Balfour & Midgley, 2008). The most implicated wild animals in crop raiding in communities adjacent to protected areas across Africa that also occur in the Hluhluwe Game Reserve are bushpig (*Potamochoerus larvatus*), elephant and primates (Barirega *et al*., 2010; Infield & Namara, 2001; Mwakatobe *et al*., 2014). Hluhluwe Game Reserve also has a range of carnivores including leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), spotted hyena (*Crocuta crocuta*) African wild dog (*Lycaon pictus*) and lion (*Panthera leo*; Infield, 1986; Owen-Smith, 1989; Balfour *et al*., 2008). African wild dogs of Hluhluwe Game Reserve have been implicated in human-wildlife conflicts in the past, but no formal reports are available (Zama Zwane; African wild dog monitor, *personal communication*). No formal reports of crop raiding have been reported near the Hluhluwe Game Reserve recently. However, three decades ago, there were reports of human wildlife conflicts around the Hluhluwe area (Infield, 1986; 1988).

Structure of the thesis

This thesis comprises seven chapters. In addition to the current chapter, there are five analytical chapters (Chapters 2-6) written up as manuscripts for publication as they provide new information and have tested novel concepts, and concludes with a general discussion chapter (7) of the thesis. Each of the 5 analytical chapters has its own abstract, introduction, methods section, results section, discussion and reference list. However, there may be some repetition of the introductory material, methodological details and/or discussion. Tables and figures are numbered sequentially within each chapter and not for the thesis as a whole. The pages for the thesis are numbered in sequence.

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Crop raiding by wildlife on subsistence homesteads in northern KwaZulu-Natal Province, South Africa

Abstract

Globally, human-wildlife conflict often arises from crop raiding. Therefore, there is a need to quantify crop damage by the suspected wildlife species around protected areas. I assessed and quantified crop damage by wildlife on subsistence farms on the edge of the Hluhluwe Game Reserve, northern KwaZulu-Natal, South Africa. Twenty farms were assessed monthly from April 2016 to March 2017, using direct observations of wildlife, detectable evidence of their consuming crops and remote camera trap footage of their presence. I recorded the animals involved in raiding, crops affected, and differences in the level of crop damage by season and farm proximity to the reserve boundary. Rodents, arthropods (mainly insects) and birds were found to feed on crops on the 20 farms, with rodents causing the highest levels of crop damage as compared to the other animals. Contrary to expectations, primates (vervet monkey *Chlorocebus pygerythrus* and chacma baboons *Papio ursinus*) were not identified as raiders during my study, since these species never left the reserve to raid farms. However, camera trap footage showed that both primate species engaged in feeding behaviour on the inside boundary edge of the reserve (close to farms) during the dry season. Maize (*Zea mays*) was the main affected crop throughout the study. The highest level of crop damage was during the dry season compared to the wet season. The distance of farms from the reserve was not a significant predictor of the level of crop damage in the farms sampled, contrary to the findings of other studies, which mentioned that crop raiding decreases away from the protected area boundary. Using systematic trapping, crop assessment and observation, my study showed that small rather than larger animals were the main crop raiders during sampling period and that maize was the most affected crop, especially during the dry season.

Key words: *camera trap survey, crop raiding, human-wildlife conflict, primates, rodents, subsistence homesteads*

Introduction

Crop raiding by wildlife is amongst the most critical problems experienced by farmers, particularly those farming adjacent to protected areas (Naughton-Treves *et al*., 1998). Higher human population densities in rural areas and more rapid conversion of forest to farmland are said to be the two principal factors contributing to crop raiding by wildlife in Africa (Plumptre *et al.*, 2002). Wildlife competes with humans for resources and damages agricultural holdings (Sitati *et al*., 2003), resulting in reduced tolerance of wildlife by farmers (Tilman *et al*., 2011). The issue of crop raiding by wildlife then becomes a national problem, differing within and between regions, for which no perfect long-term solutions have yet been found (Sitati *et al*., 2005). Crop raiding is a significant concern for farmers and conservationists (Chiyo *et al*., 2005; Priston & Underdown, 2009; Sitati *et al*., 2005; Thenkabail *et al*., 2010). However, the extent of the problem has not been addressed in subsistence farmers (Seoraj-Pillai, 2016; Treves, 2008). Thus, case-specific studies are needed from farmland bordering protected areas, with different potential crop types and crop pests, to enable us to generate a global understanding of crop-raiding patterns (Osborn & Parker, 2003).

Wildlife will often forage on agricultural land (Naughton-Treves, 1997; Sukumar, 1990). Several candidate mammal species have been identified to cause crop damage worldwide. In Africa, the main crop raiders are bush pig (*Potamochoerus larvatus*) (Gunn, 2009; Sillero-Zubiri & Switzer, 2001), elephant, hippopotamus (*Hippopotamus amphibus*) (Parker *et al*., 2008; Tilman *et al*., 2011), primates, such as vervet monkey (*Chlorocebus pygerythrus*) and redtail monkey (*Cercopithecus ascanius*) (Hoare, 2001; Naughton-Treves *et al*., 2008; Saj *et al*., 2001; Sitati *et al*., 2003) and a variety of rodents, such as crested porcupine (*Hystrix africaeaustralis*) (Kavanagh, 1980) and cane rats (*Thryonomys spp*.; Kavanagh, 1980). Crop raiding by wildlife has been extensively studied in Africa (Hill *et al*., 2002; Hoare, 2001; Sitati *et al*., 2003; Treves, 2008), with focus being placed on flagship species such as elephant (*Loxodonta africana*) (Naughton-Treves, 1997; Sillero-Zubiri & Switzer, 2001; Treves, 2008). However, raiding by rodents and primates has received little attention in the scientific literature, mainly because attention has been given to larger mammals (Hill *et al*., 2002; Hoare, 2012) in human-wildlife conflict studies.

Naughton-Treves (1997) maintained that, on a global scale, crop losses due to large mammals are insignificant compared to those due to invertebrates and small mammals.

Small mammals do not form a zoological group but are generally considered to be mammals weighing 1kg or less when adult (Kuiper & Parker, 2013). They have the potential to cause extensive damage to farms mainly because they are not always noticeable and can transgress fences with ease because of their small size (Chiyo, 2005). In particular, rodents are blamed for damage to standing crops and granaries (Lahm, 1996; Naughton-Treves *et al*., 1998). In Asia, the rice loss every year caused by rodents could feed 200 million people (Stenseth *et al*., 2003). In Europe, the fossorial water vole (*Avicola Scherman*) feeds on tree roots, causing considerable damage to apple orchards (Miñarro *et al.,* 2012). In Palestine, Albaba (2016) showed that the Levant vole (*Microtus guentheri*) caused damage to crops such as cereals, fodder crops, and vegetables.

Systematic surveys of rodent damage are scarce in Africa (Amundala *et al*., 2008; Arlet & Molleman, 2007). Some examples of crop raiding rodents in Africa are the common mole-rat (*Cryptomus hottentotus*) (Naughton-Treves *et al*., 1998), South African ground squirrel (*Xerus inaurus*), spiny mouse (*Acomys spinosissimus*), cane rat (*Thryonomys* spp.), multimammate mouse (*Mastomys natalensis*) (Thiel, 2011) and crested porcupine (Naughton-Treves, 1997; Sitati *et al*., 2003). However, the impact of these animals on subsistence homesteads is not well documented (Priston, 2008).

In most African and Asian countries, non-human primates (hereafter primates) pose severe problems as crop raiders and are responsible for over 70% of damaging events to field crops (Hill, 2002; Naughton-Treves *et al*., 1998). In Uganda, for example, Tilman *et al*. (2011) found that several primate species can contribute to crop raiding, in particular the chimpanzee (*Pan troglodytes*), chacma baboon (*Papio ursinus*) and vervet monkey (*Chlorocebus pygerythrus*) were reported by farmers to be the leading contributors of crop losses. The relationship between people and primate pests can be complex, however (Eudey, 1994). In parts of Zanzibar, Sykes monkeys (*Cercopithecus albogularis albogularis*) are worshipped, protected and provisioned by villagers (Eudey, 1994; Jolly, 1985; Malik & Johnson, 1994); while showing remarkable tolerance, people staying in these parts are still reluctant to share their crops with the monkeys (Richard *et al*., 1989; Southwick *et al*., 1961). This conflict is also highlighted in Japan and Nepal where Japanese macaques monkey (*Macaca fuscata*) and free ranging rhesus macaque monkey (*Macaca mulatta*) are provisioned in one temple or village (Chalise, 2003) and shot in the neighbouring field (Regmi *et al*., 2013).

The dietary overlap between primates and humans, coupled with their ecological flexibility and behavioural plasticity, can lead to primates destroying a wide range of crops (Hill, 1997; Siex & Struhsaker, 1999). Thus, crop damage by primates varies from complete consumption of items, biting (presumably to sample) to trampling crop plants (Mwakatobe *et al*., 2014). However, some studies indicate that primates target specific foods, such as fruits for sugar and leaves and nuts for protein, to meet their nutritional requirements and metabolic demands (Mwakatobe *et al*., 2014; Webber *et al*., 2007). For example, mountain gorilla (*Gorilla beringei*) raids only banana crops in Rwanda (Campbell-Smith *et al*, 2008).

The ability to climb and a high level of individual and social cognition (Treves, 2008) enables primates to easily transgress park boundaries (Hill, 2002). Traditional and non-traditional protection strategies, such as creating barriers (electric fences, walls, and ditches) are usually ineffective against primates, which can negotiate their way through or over most forms of fencing (Siex & Struhsaker, 1999) and are quick to learn how to transgress through electric fences without being harmed (Strum, 1994). Unsurprisingly, crop raiding by primates is common, yet studies of primate feeding ecology do not adequately consider their impact on subsistence homesteads, as well as seasonal changes in their raiding behaviour changes for agricultural and non-agricultural food (Linkie *et al*., 2007; Naughton-Treves *et al*., 1998).

Most common crops raided near protected areas in Africa are maize (*Zea mays*), cassava (*Manihot esculenta*), rice (*Oryza sativa*), sugar cane (*Saccharum officinarum*), banana (*Musa* spp.) and common beans (*Phaseolus vulgaris*; Hill, 2000; Naughton –Treves *et al*., 1998). In Western Uganda, Hill *et al*, 1997) found that maize, sweet potatoes (*Ipomoea batatas*) and cassava were considered to be the crops most vulnerable to raiding, while sorghum (*Sorghum bicolor*), banana and taro (*Colocasia esculenta*) were the least vulnerable. In Uganda, Tweheyo *et al*. (2005) found 21 crop types being raided, with the most frequent being rice, maize, cassava, sugar cane, and banana. Damage to sown crops (i.e. sorghum, millet, common bean, maize, and cassava), the most common subsistence crops in Africa, results in human-wildlife conflicts in most African countries (Mwakatobe *et al*., 2014).

Most crop raiding by wildlife is reported to occur on farms that are in close proximity to protected areas (Hill *et al*, 2002; Naughton-Treves, 1997). Naughton-Treves (1997) hypothesised that crop raiding, in general, is limited to a few hundred metres from the protected area boundaries. This hypothesis has received mixed support in the literature

(Falls, 1993; McLennan *et al*., 2012; Mutanga, 2008; Newton-Fisher, 2003). Mutanga (2008) found that crop damage by eland (*Taurotragus derbianus*) in Kamberg Nature Reserve, KwaZulu-Natal Province happened only on farms that were in close proximity to that nature reserve boundary. In contrast, Falls (1993) found that around the Suikerbosrand Nature Reserve, Gauteng Province, chacma baboon (*Papio ursinus*) damaged farmlands and also caused damage in towns up to 40 km^2 from the reserve. These differences reflect the comparative ease with which wildlife can transgress park boundaries. However, I am not aware of any studies that have tested the distance-related hypothesis for rodents and primates in rural subsistence farmers of South Africa.

I investigated the levels of crop raiding by rodents and primates in a subsistence farming community, abutting the Hluhluwe Game Reserve, KwaZulu-Natal Province, South Africa. The literature maintains that crop-raiding levels vary seasonally (Campbell-Smith *et al*., 2010; Chiyo *et al*., 2005; Hill, 2002; Sitati *et al*., 2003). In particular, it is reported that crop-raiding incidences decrease during the wet season; crop damage by wildlife often increases when alternative food sources in the environment become scarce, such as in the dry season (Tweheyo *et al*, 2005). Therefore, I predicted that the level of crop damage by both rodents and primates would increase during the dry season from April to August and decrease during the wet season from September to March. I also tested the hypothesis proposed by Naughton-Treves (1997) that crop raiding decreases away from the game reserve boundary. I assessed the level of crop damage by rodents and primates seasonally in farms situated at various distances (up to 3km) from the Hluhluwe Game Reserve boundary. I predicted that the level of crop damage by both rodents and primates would be greater on farms that are closer to the game reserve compared to farms further away from the game reserve. I also predicted that maize (*Zea mays*) would experience the highest level of damage as compared to all the other crop types. Previous research has reported that maize is the most depredated crop because of its nutritional value (Hill, 2000; Naughton-Treves, 1997; Treves *et al*., 1998). Treves *et al*. (1998) reported that maize (ripe and dried) was the most frequently eaten crop by animal crop raiders in West Africa.

Materials and methods

Study site

The study was conducted at Phindisweni village (28°26' S; 31°43 'E), bordering the Hluhluwe Game Reserve (Fig. 2.1). The village occupies an area of 1375 km^2 (StatsSA, 2011), located in a mountainous region, with its highest peak at 650 m above mean sea level (StatsSA, 2011). The area is hot (temperature range 13° C – 28° C annually), with the rainy season from late September to March. Subsistence farming is the main source of income in this community (StatsSA, 2011). Most crops grown in this community are annual crops, such as maize (*Zea mays*), spinach (*Spinacia oleracea*), cabbage (*Brassica oleracea*), beetroot (*Beta valgaris*) and common bean (*Phaseolus vulgaris*). Yam (*Oxalis tuberosa*), a perennial herbaceous crop, and fruit, such as banana (*Musa spp*), mango (*Mangifera indica*), peach (*Prunus persica*) and pineapple (*Ananas comosus*) are also cultivated.

Phindisweni village is vulnerable to crop raiding according to previously undocumented farmer reports. I sampled wildlife in 20 subsistence farms adjacent to the Hluhluwe Game Reserve (Fig. 2.1) in the dry (April to August) and wet (September to March) seasons from April 2016 to March 2017. These farms were selected for study (with the assistance of two field assistants) based on their accessibility and proximity to the reserve.

Farm attributes

A Garmin GPSMap62 handheld device was used to record several farm attributes. I recorded the geographical location (GPS coordinates of the farms) and elevation of the central position of each of the 20 farms sampled. The area of each farm and the area cultivated were established by walking the perimeter of each sampled farm and cultivated land separately and calculating the area of each in m^2. The distance between each farm and the reserve boundary was determined by a straight-line shortest distance from the centre of the farms to the reserve boundary fence using ArcMap (ArcGIS, V10.3, software package, ESRI). The measurements were grouped into intervals of <1km, 1-2km and 2-3km.

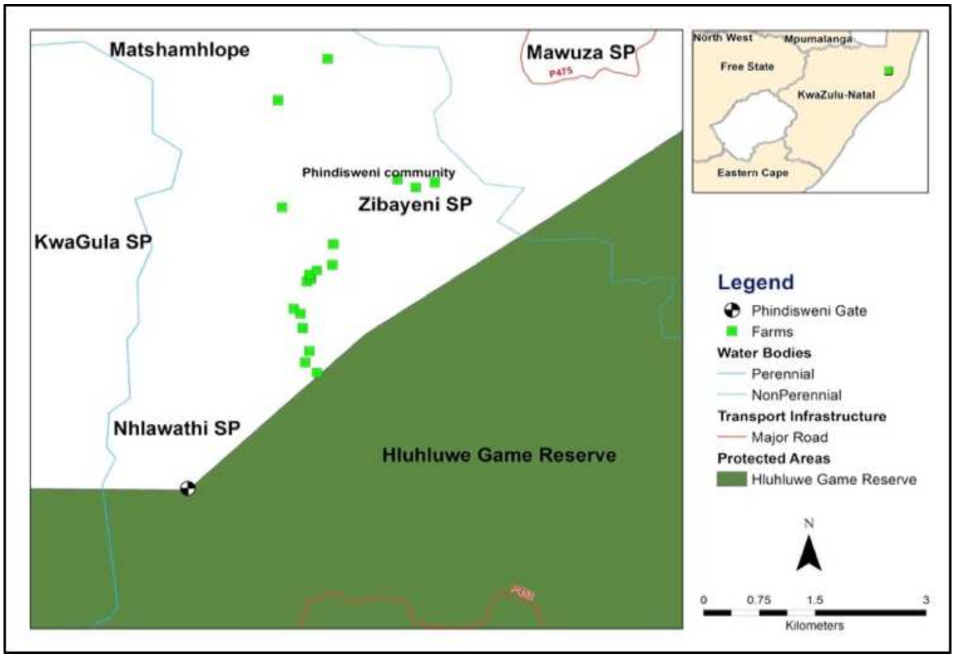

Figure 2.1. Map showing the location of Phindisweni community with the sampled farms (green squares), on the edge of Hluhluwe Game Reserve. Inset: KwaZulu-Natal Province, showing the study site in South Africa.

Farm sampling

I sampled food crops at Phindisweni farms (Figure 2.1), during the dry season and the wet seasons. 1m^2 quadrats were placed to cover at least 20% of the cultivated area for each farm. Quadrats were randomly placed flat on the ground in the farmed areas and left lying there for 10 consecutive days each month per farm throughout the study. The joint ends of the quadrats were covered in bright insulation tape to locate the quadrats later. Most farmers planted their crops in rows (personal observation). Therefore, the quadrats were placed to cover all crop types planted per farm. To cover at least 20% of the cultivated land, I set 6 to 16 quadrants, depending on the surface area of the cultivated land in each farm.

Crop damage assessment

I visited the farms for 10 consecutive days, twice a day every month for the duration of the study to assess the amount of damage caused by animals on food crops. I counted the number of individual food crops damaged daily in each quadrat, irrespective of where the damage occurred (i.e. mostly on the leaves of crops or seeds for maize). The damaged part/s of the plants were pricked with a pin around the destruction sites to identify damage and to avoid later resampling. Crop types were also recorded. Animals that were directly observed causing damage were arthropods (mainly insects) and birds (species unknown). Even though rodents were trapped inside the farms (see Results), they were never witnessed directly feeding on crops. Therefore, I used impressions and indentations on food crops to identify damage. I used the following evidence to categorise crop raiders: rodents, from tooth marks and ragged breaks with shredded edges and holes; insects from round holes on the leaves; and birds from tears off the food crops (**Supplementary material**: Figure S1). Crop damage was quantified by counting the total number of damaged crop parts, mostly leaves (sampling unit), of each individual food crop inside each quadrat, and was recorded as the level of crop damage by rodents, insects and birds in a farm. Since I used impressions and indentations on food crops to identify damage, in cases where more than one crop raider damaged a crop part I recorded the damage by each crop raider suspected to have caused the damage. The total number of counts per quadrat for a particular crop and pest species was recorded. Because the focus of the study was on rodents, the damage that was caused by other pests (insects and free-living birds) was compared to the damage caused by rodents.

Rodent trapping

The capture, mark, identify and release protocol technique was used to sample rodents. Trapping was done monthly from April 2016 to March 2017. Each trapping session lasted 10 consecutive days each month per farm. PVC live-traps (290 x 60 x 80 mm) were set randomly on each farm, resulting in 1200 (smallest farm) to 1680 (largest farm) trap nights. Traps were baited with a mixture of peanut butter, oats, coarse salt, sunflower oil, and raisins (Dolan *et al.*, 2011). Cotton wool was inserted into traps to provide insulation for trapped animals during the colder periods. Also, I covered traps with surrounding vegetation for insulation against lethal temperatures.

Traps were set in areas preferred by small mammals, such as next to fallen trees/shrubs, next to holes in the ground and areas with small mammal runways. Traps were checked twice a day, once in the morning (9 am to 10 am) and in the afternoon (3 pm and 5 pm). I identified trapped individuals to species. The trapped animals were transferred from the traps to a clear plastic bag and weighed (to the nearest gram) using a DKD handheld spring balance. Individuals were sexed based on the ano-genital distance and obvious genital differences. To recognise previously captured individuals, I marked each captured individual by trimming the hair on the back of the neck with a pair of scissors to reveal the different colour undercoat (Mills *et al*., 1999). Gentian violet was sprayed on the clipped area as a semi-permanent marking to also assist in identifying recaptures. The individuals were released at the point of capture and the traps were re-baited when necessary. Trapping was conducted with the approval of the local government conservation authority, Ezemvelo KZN Wildlife (permit number: OP 711/2016), and the University of the Witwatersrand Animal Ethics Screening Committee (AESC protocol number: 2015/011/48/B).

Monitoring primates

Direct observation and camera trap methods were used to sample primates for this study. The 20 farms were sampled for four hours a day randomly from 6 am to 8 am and, again, from 4 pm to 6 pm for 10 days a month from April 2016 to March 2017. To assess primate behaviour in the mornings and the afternoons before they disappeared into the surrounding bush, I walked along the sampled farms to identify whether they raided crops. During these walks, I aimed to record the presence and demographic parameters (number of groups, juveniles, and adult males and adult females) of primates raiding crops and the type of crops they raided. We (my field assistants and I) carried a digital camera during the walks to capture any evidence of crop raiding, as well as other evidence, such as droppings, bite marks on crops, and tracks. However, throughout the study, primates never transgressed the reserve boundary to raid crops. Therefore, their potential to raid crops was analysed from the camera trap footage (see below), to assess their behaviour on the edge of the reserve.

Camera trap surveillance

At 10 sites determined to be frequently visited by primates, according to farmer reports, I set up 10 x 8-megapixel infrared camera traps (Bushnell®, trophy camera, China), with 32 GB memory cards. The cameras were positioned at appropriate angles at approximately 0.7 m above the ground. All the cameras faced onto the farms and were secured using multiple lengths of coated flexible wire and a padlock to prevent theft. Also, for five farms that were adjacent to the Hluhluwe Game Reserve, the cameras were set up strategically facing the reserve to record the occurrence and behaviour of primates and other mammals, particularly if they transgressed the reserve/farm boundary. The five farms were separated from the reserve by a gravel road that was created by reserve management as a safety measure for fence workers. The five farms shared a fence with the reserve and with each other, and were separated by distance of 100 m from each other.

The cameras were housed within an aluminium camera housing to reduce damage from moisture and for protection from rain, and tied to tree trunks/logs. The camera started recording when a motion was sensed at a distance up to 18 m and recorded high definition videos (1280×720 pixels) for 30s. A delay period of 15s between recordings was programmed into cameras to avoid too many records of a single motion trigger. The videos were automatically dated and time stamped. Cameras were operational 24 hours a day for 10 days per month in each of the sites throughout the study and checked every three days to replace data storage card and batteries, if necessary. Video footage was downloaded onto a laptop computer from each memory card every three days and organised into folders labelled with the location and date.

All visible animals on the video footage were identified according to primates or in other broad animal categories. The frequency of occurrence of primates and other animal groups on the edge of Hluhluwe Game Reserve were noted. To avoid pseudo-replication of primates and other animals on one video, I scored each animal species as one occurrence per day from the video footage, regardless of the number of times per day they appeared in the footage. I also recorded each primate's behaviour (feeding and traveling) by season separately.

To investigate the potential of primates to raid crops, I scored two behaviours, feeding (i.e. manipulation and ingestion of food), considered to have priority over other activities (Kurup & Kumar, 1993), and traveling (i.e. walking, running) which was found to have a positive relationship with feeding in Japanese macaque (*Macaca fuscata*) (Agetsuma *et al.*, 1995). The travelling and feeding behaviours are fundamentally important when addressing the crop-raiding behaviour of primates because these two behaviours are indicative of current or future raiding. Agetsuma *et al.* (1995) found that Japanese macaques decreased feeding time when fruits are available and increase traveling time when the density of fruit-food trees is low during the dry season, requiring greater travelling and searching for trees.

Statistical analyses

Rodent trapping data were analysed using descriptive statistics because of the small sizes. All other statistical analyses were done using R statistical software (version 3.3.3;

2017). Statistical tests were two-tailed, and significance levels were set at $P \leq 0.05$. Data were mostly categorical and did not meet the assumptions of normality (Shapiro-Wilk test). Accordingly, nonparametric analyses were used.

The Spearman's rank order correlation coefficient (Spearman's rho) was performed to analyse the relationship between farm proximity to the reserve boundary and the level of crop raiding by animal groups separately (rodents, insects, birds) and collectively. For each species, the level of crop damage was set as the response variable and distance from the game reserve was the explanatory variable.

To assess seasonal variations in the level of damage by 1) crop type and 2) crop raiding animals, I applied two separate Generalised linear mixed models (GLMM) with a *glmer* function and a Poisson distribution (lme4 package, Bates *et al*. 2015). For both models, I included farm size as a random factor (intercepts only) to account for the potential sizes effect. I checked the model fit for the variables described below, and used the most appropriate model, based on the plot of the residuals against the fitted values from each model (Crawley, 2007). For model 1: I used season, crop raiding animals, and two-way interactions of season*crop raiding animals as independent variables with the level of damage as a dependent variable and for model 2: I used season, crop type and the interaction between season*crop type as independent variables with the level of damage as the dependent variable. I generated P values using likelihood ratio tests (Bates *et al*. 2015).

Primates did not transgress the reserve boundary to raid crops throughout the study. Therefore, I investigated their potential to raid crops by assessing their behaviour on the edge of the reserve. I analysed the numerical frequencies of occurrences (1 occurrence per day; see above) of two behaviours (travelling and feeding) along the reserve boundary for chacma baboon (*Papio ursinus*) and vervet monkey (*Chlorocebus pygerythrus*) separately with Generalised linear models (GLMs), with a *glm* function and Poisson distribution. I included season, species, and the two-way interactions season* species as independent variables. Significance was determined using Wald (χ^2) statistics. Data for this study are presented as boxplots and scatterplots, produced using a Ggplot2 package from R software.

Results

Rodent trapping

A total of 96 individual rodents were captured in 20 sampled farms from April 2016 to March 2017, in 30600 trap nights (0.3% trap success), comprising of two species: red bush rat (*Aethomys spp.*) and pouched mouse (*Saccostomus campestris*). *Aethomys spp.* (67.7%; 51 males and 28 females) was most commonly trapped, and is a common murid rodent in savanna habitats in KwaZulu-Natal Province (McGuinness *et al*., 2014). The pouched mouse (*Saccostomus campestris*) represented the remaining 32.3% (14 females and three males). Both the *Aethomys spp* and the *Saccostomus campestris* were mostly captured during the dry season.

Crop raiding and farm proximity to the game reserve

The Spearman's rho did not reveal a statistically significant relationship between the level of damage and distance of farms from the reserve boundary (r_s = -0.07, P = 0.438), although the highest level of damage was in farms further away from the reserve (Figure 2.2).

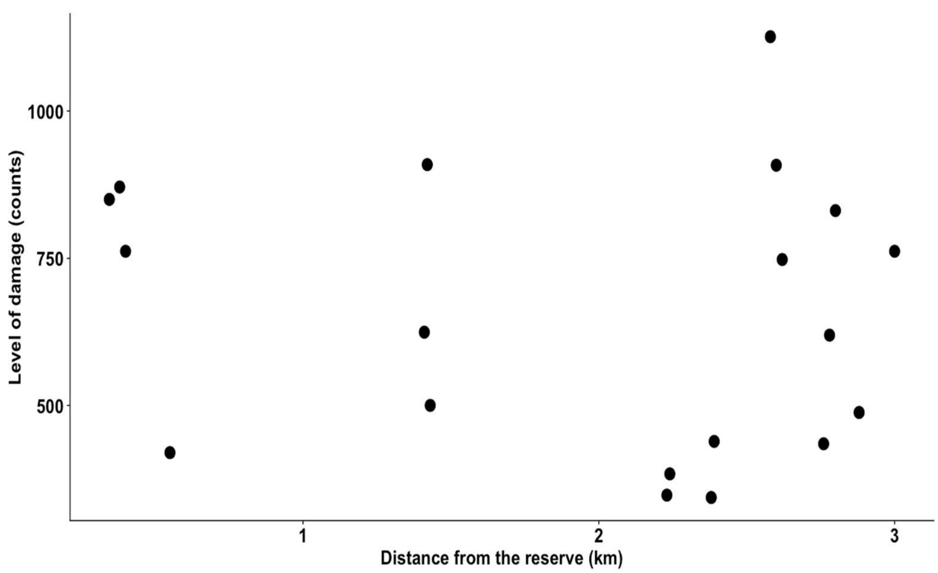

Figure 2.2. Scatterplot of the distribution of the overall level of crop damage (counts per farm) across different farm distances for 20 sampled farms abutting the Hluhluwe Game Reserve, South Africa.

I then ran three separate Spearman rank analysis for the different crop raiding animal type (rodents, insects and birds) to ascertain the relationship between the distance of farms from the reserve boundary and the level of crop damage. There was again no significant correlation between farm distance from the reserve boundary and the level of crop damage by rodents (r_s = -0.18, P = 0.262), insects (r_s = -0.06, P = 0.700) and birds (r_s = -0.09, P = 0.601; Figure 2.3).

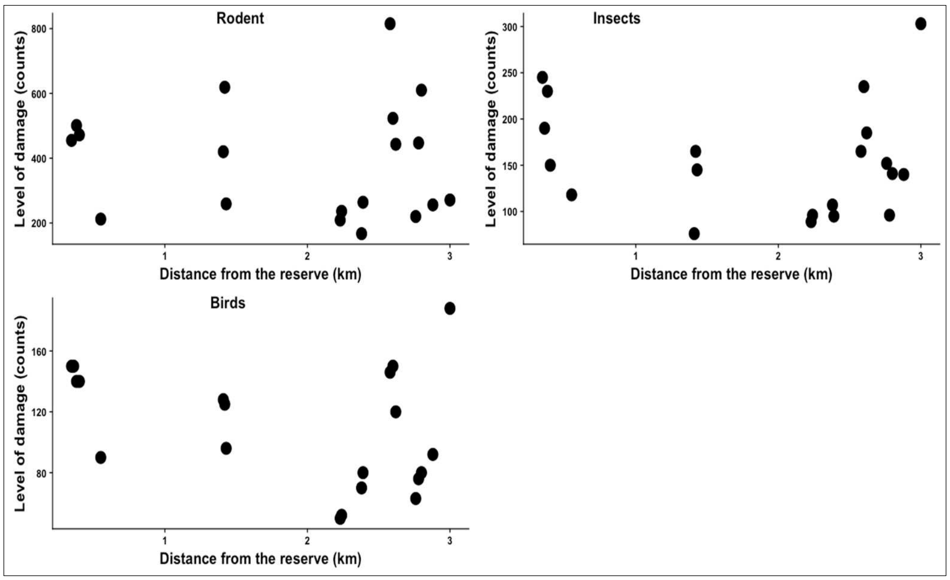

Figure 2.3. Distribution of the levels of crop damage (counts per farm) by crop raiding rodents (top left), insects (top right) and birds (bottom left) across 20 sampled farms situated at different distances from Hluhluwe Game Reserve, South Africa.

Variation in the level of crop damage by crop raiding animals

The results of a GLMM showed that season (Wald χ^2_1= 17.02; P < 0.001), crop raiding animal type (Wald χ^2_1= 302.76; P < 0.001) and the interaction between season and crop raiding animal type (Wald χ^2_2 = 165.57; P < 0.001) were significant predictors of the level of damage. Farmers experienced the highest level of crop damage during the dry season as compared to the wet season. Rodents followed by insects and birds caused the highest level of crop damage. The highest level of crop damage was caused by rodents during the dry and wet season as compared to insects and birds, but the highest level of rodent crop damage was during the wet season as compared to the dry season in contrast to the highest level of crop damage caused by insects and birds, which was in the dry season (Figure 2.4).

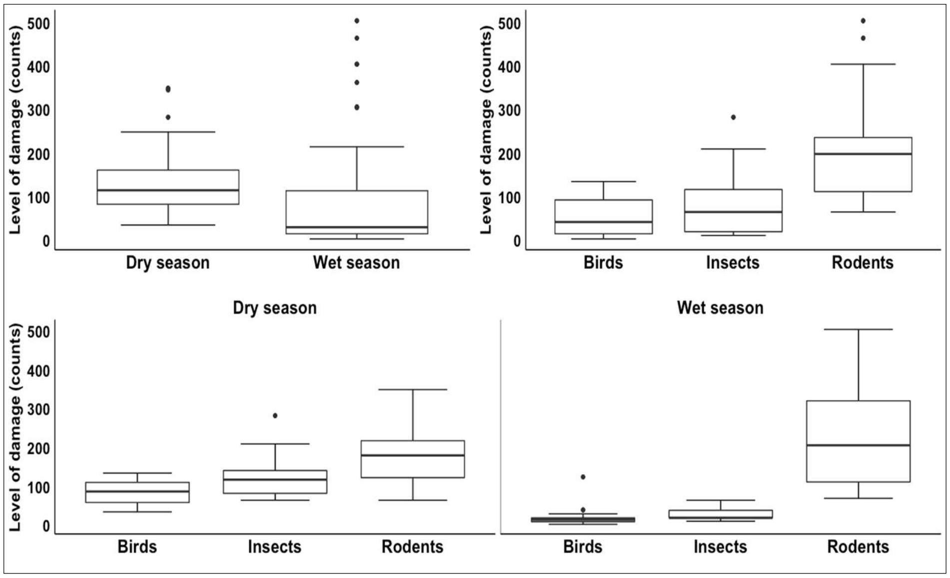

Figure 2.4. Levels of damage (counts per farm) by season (top left), crop raiders (top right) and season*crop raiders (bottom) in farms on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and dots outside of boxes indicate outliers.

Variations in the level of crop damage by crop type

The GLMM results showed that season (Wald χ^2_1 = 962.23; P < 0.001), crop type (Wald χ^2_4 = 7725.42; P < 0.001) and the interaction between season and crop type (Wald χ^2_3 = 118.25; P < 0.001) were significant predictors of the level of damage. Farmers experienced the highest level of crop damage during the dry season as compared to the wet season. The highest level of crop damage was for maize followed by spinach, common bean and beetroot. Crop damage for maize was higher during both the dry and wet season than the damage for all the other crop types, but the highest level of damage for maize and the other crop types was during the dry season than the wet season (Figure 2.5).

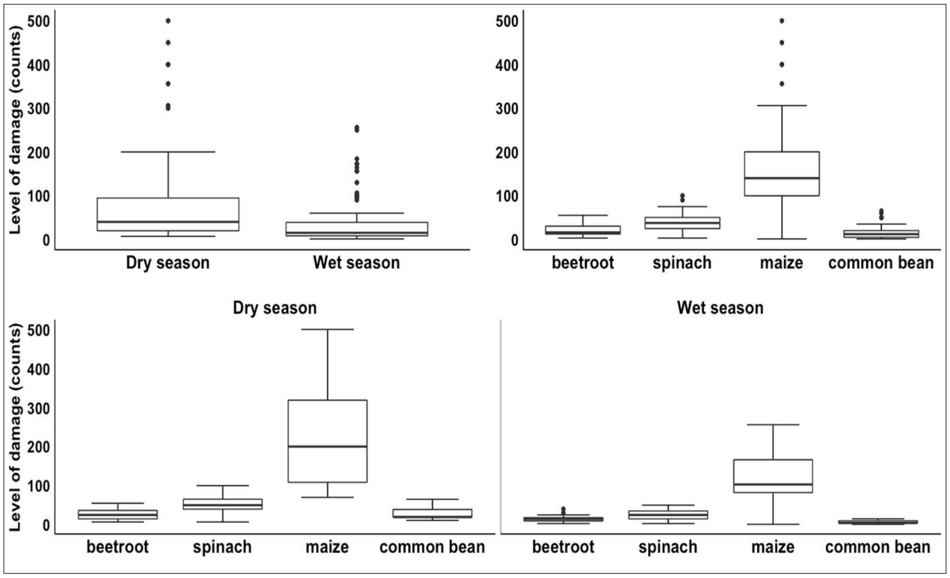

Figure 2.5. Levels of damage (counts per farm) by season (top left), crop type (top right) and season*crop type (bottom) in farms on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and dots outside of boxes indicate outliers.

Seasonal variations in primate behaviours

Overall, primate occurrence along the reserve boundary was significantly influenced by season (Wald χ^2_2 = 1358.33; P < 0.001) and species (Wald χ^2_1 = 12.43; P = 0.000), with the highest occurrence recorded during the dry season as compared to the wet season and the highest occurrence recorded for vervet monkey compared to chacma baboon. Primate occurrence along the reserve boundary was not significantly influenced by the interaction between season and species (Wald χ^2_1 = 2.36; P = 0.124, Figure 2.6).

Feeding behaviour

Species (Wald χ^2_1 = 3.19; P = 0.073) and the interaction between species and season (Wald χ^2_1 = 0.11; P = 0.736) were not significant predictors of the feeding behaviour of chacma baboons and vervet monkeys along the reserve boundary. Feeding behaviour was significantly influenced by season (Wald χ^2_2 = 16.41; P = 0.000), with the highest feeding behaviour occurring in the wet season as compared to the dry season (Figure 2.7).

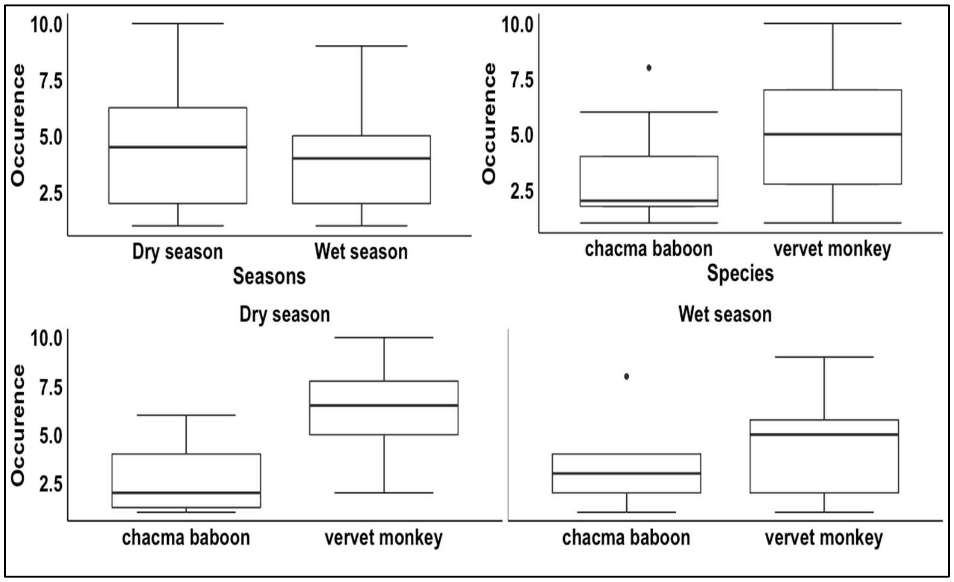

Figure 2.6. Frequency of primate occurrences by season (top left), species (top right) and season*species (bottom) along the Hluhluwe Game Reserve boundary, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and the dot outside of boxes indicate outliers.

Travelling behaviour

Season (Wald χ^2_2 = 18.70; P < 0.001), species (Wald χ^2_1 = 10.86; P = 0.000), season*species (Wald χ^2_1 = 5.28; P = 0.021) had a significant effect on the frequency of the travelling behaviour of primates along the Hluhluwe Game Reserve boundary. The most frequent occurrence of travelling behaviour was recorded during the dry season as compared to the wet season. Vervet monkeys travelled along the reserve borders more frequently than chacma baboons. The highest frequency of occurrence of the travelling behaviour by vervet monkey was during the dry season as compared to the wet season Figure 2.8).

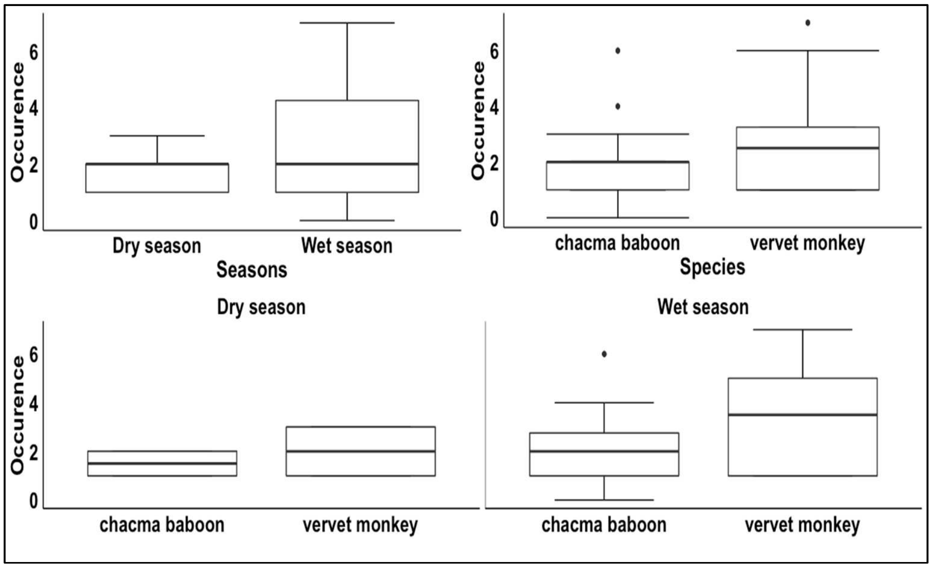

Figure 2.7. Frequency of occurrence of primate feeding behaviour by season (top left), species (top right) and by season*species (bottom) along the Hluhluwe Game Reserve boundary in South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and the dot outside of boxes indicate outliers.

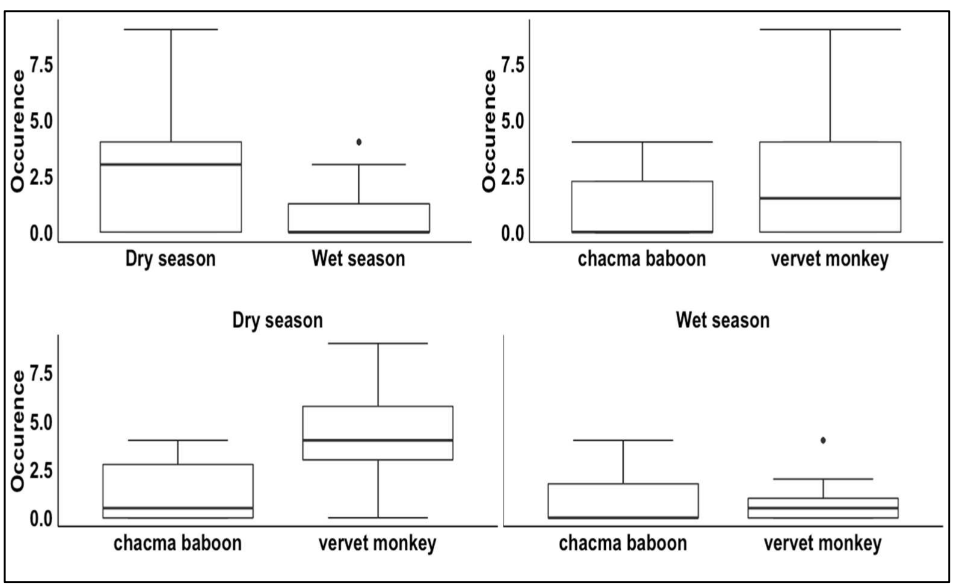

Figure 2.8. Frequency of occurrence of primates travelling behaviour by season (top left), species (top right) and by season*species (bottom) along the Hluhluwe Game Reserve boundary in South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and the dot outside of boxes indicate outliers.

Monitoring primates and other animals

The camera trap activity generated a total of 2 051 non-domesticated animals captured by the automatic activation of the video-trap in 2 266 620 video clips of 30 seconds each for the duration of the study. The animals that were captured on the camera traps were at the inside edge of the reserve, and were categorised into six animal groups as follows: antelope, birds, carnivores, primates, other herbivores (Table 2.1). Primates were the fourth most abundant free-living animal group captured by the camera traps amongst the six groups. The chacma baboon and vervet monkey were captured in 165 video clips (an animal species was counted as one occurrence per day to avoid pseudo sampling) with 36.36% being chacma baboons (n = 60) and 63.63% vervet monkeys (n = 105; Table 2.1). The leading wild animals captured by the camera traps were (elephant *Loxodonta africana,* nyala *Tragelaphus angasii* and impala *Aepyceros melampus*; Table 2.1).

Table 2.1. Number of occurrences (N) and frequency of occurrences (%N) for animals captured (n=2051) by camera traps on the edge of Hluhluwe Game Reserve, South Africa from March 2016 to February 2017.

Animal group	Species	Common name	N[1]	%N[2]
Antelope			**822**	40.07%
	Tragelaphus strepsiceros	Kudu	105	5.11%
	Cephalophus natalensis.	Red duiker	63	3.07%
	Tragelaphus angasii	Nyala	410	19.99%
	Aepyceros melampus	Impala	244	11.89%
Birds			**41**	1.99%
	Gutterra pucherani	Crested Guinea Foul	10	0.48%
	Ephippiorhynchus senegalensis	Saddle-billed Stork	2	0.09%
	Bugeranus carunculatus	Wattle Crane	4	0.19%
	Balearica regulorum	Grey Crowned Crane	7	0.34%
	unknown species	_	18	0.87%

Carnivores			**149**	7.26%
	Panthera leo	African lion	62	3.02%
	Lycaon pictus	African Wild dog	68	3.31%
	Crocuta crocuta	Spotted hyena	6	0.29%
	Ichneumia albicauda	White-tailed Mongoose	4	0.19%
	Galerella sanguinea	Slender Mongoose	7	0.34%
	Genetta genetta	Common genet	2	0.09%
Primates				
			165	8.04%
	Chlorocebus aethiops	Vervet monkey	105	5.11%
	Papio ursinus	Chacma baboon	60	2.92%
Other herbivores			**874**	42.61%
	Loxodonta africana	African elephant	566	27.59%
	Syncerus caffer	Buffalo	78	3.80%
	Connochaetes	Wildebeest	105	5.11%
	Phacochoerus africanus	Warthog	101	4.92%
	Potamochoerrus larvatus	Bush pig	24	1.17%
Totals[3]			**2051**	**100%**

[1]N=number of animal species captured by the 10 camera traps on the edge of the reserve.

[2]%N=percentage of the animals photographed obtained by dividing the number of a species (N) by the total number of all the animals captured (N=2051) and multiplying by 100

[3]Totals of N and %N were obtained by adding the number (N)/N% of animal groups indicated in bold on the table.

Discussion

I investigated the levels of crop damage by rodents and primates in a subsistence farming community, abutting the Hluhluwe Game Reserve in KwaZulu-Natal Province, South Africa. I assessed aspects of crop damage by crop raiding animals and crop type, and evaluated the hypothesis by Naughton-Treves (1997) that crop raiding decreases away from the game reserve boundary. Primates never transgressed the farm boundaries to raid crops throughout the study. I therefore investigated primate behaviour along the borders of Hluhluwe Game Reserve, to assess their potential to raid crops.

I trapped 96 individual rodents of two species (79 *Aethomys spp* and 17 *Saccostomus campestris*). These two murids are common in the savanna biome (Skinner & Chimimba, 2005; De Graaff, 1981) and were also reported by other studies in the Hluhluwe-iMfolozi Game Reserve complex (Hagenah *et al*., 2009; Taylor, 1998). However, these two species are not the most common species in the study area (Hagenah *et al*., 2009). Thus, the diverse assemblage of rodents present at Hluhluwe Game Reserve was not reflected in my study. The reduced rodent species richness and diversity in my study was an indication of a disturbed ecosystem, probably also due to the drought disaster that was experienced during the study in the study area.

Several rodent species have been recorded in the Hluhluwe Game Reserve, including the Natal multimammate mouse (*Mastomys natalensis*), pouched mouse (*Saccostomus campestris*), single striped mouse (*Lemniscomys rosalia),* fat mouse (*Steatomys pratensis*), African pygmy mouse (*Mus minutoides*), bushveld gerbil (*Gerbilliscus leucogaster*), Southern African vlei rat (*Otomys spp*) and grey African climbing mouse (*Dendromus melanotis*; Dumalisile & Somers, 2017; Hagenah *et al*., 2009; Skinner & Chimimba, 2005).

In the past two decades, the most common murid rodent in Hluhluwe Game Reserve has been the single striped mouse (*Lemniscomys rosalia*; Hagenah *et al*., 2009; Taylor, 1998), with Hagenah *et al*. (2009) reporting that *Lemniscomys rosalia* represented 75% of total small mammal captures. The single striped mouse subsists largely on grass and seeds (De Graaff, 1981). Firquet *et al*. (1996) found vegetable matter in the *Lemniscomys rosalia* diet list, yet I did not trap this species in adjacent farms. However, Monadjem (1997) mentioned that the most important habitat requirement of *Lemniscomys rosalia* is dense ground cover of long grass. The absence of long grass amidst the drought that was experienced during my study could explain why this species was not captured by this study. This drought might have also affected other rodent populations in the study area. Several studies have shown that the amount of vegetation is important for protecting rodents from predators and will influence the presence/absence in an area (Birney *et al*., 1976; Cook, 1959).

There are other reasons for only two rodent species being trapped on the farms. *Saccostomus campestris* and *Aethomys spp* are recognised as seedeaters (De Graaff, 1981; Mushasha, 1999), feeding on a variety of seeds (Kerley *et al*., 1992; Monadjem, 1997).

However, studies in other parts of their distribution range suggest that they are omnivorous, with a diet often including foliage (Miller Maxine, 1994; Monadjem, 1997). In addition, Kinahan & Pillay (2008) suggested, based on the size and complexity of the gut, that they have a generalist herbivorous diet. Both species can make use of modified landscapes, including degraded grasslands, gardens (De Graaf, 1981), and farmlands, as indicated in my study. In Hluhluwe-iMfolozi Game Reserve complex, both *S. campestris* and *Aethomys spp* were captured only in the absence of larger herbivores, whereas *Lemniscomys rosalia* was captured regardless of the presence of large herbivores (Hagenah *et al*., 2009). *Saccostomus campestris* abundance increased during drought periods in the Hluhluwe-Mfolozi Game Reserve (Bowland & Perrin, 1989). In summary, the absence of some species (e.g. *Lemniscomys rosalia* and the multimammate mouse *Mastomys natalensis,* which also occurs in the study area), the open habitat and drought conditions might have favoured the occurrence of *Aethomys spp.* and *Saccostomus campestris*.

I found differences in the level of crop damage between rodents, insects and birds, as well as differences in their level of crop damage between the dry and the wet season. Worldwide, rodents are considered as the second most important pest of farms (after insects), but farmers claim to have the least control of rodent pests (Tilman *et al*., 2011). In Uganda, Hill (1997) found that rodents, insects, and birds caused widespread damage to crops. Moreover, Sitati *et al*. (2003) found that the patterns of crop raiding by rodents appear to be similar to those of birds and insects in that they are widespread and they can inflict relatively large losses on farmers irrespective of the distance of the farms to protected areas. In the context of Hluhluwe Game Reserve, the subsistence farmers selected for study used pesticides to control insects once a month and birds were controlled by throwing stones at them (personal observation). The higher levels of crop damage caused by rodents in both seasons may therefore be due to their not being “controlled”, as were insects and birds. Rodents can cause greater levels of damage compared to larger mammals because they can transgress farms with relative ease and can hide and utilise vegetation cover. Albaba (2016) found that, in Palestine, rodents caused considerable damage to rice plantations because of their ability to hide and utilise vegetation cover.

I did not find any indication of raiding by primates. Instead, primates were observed feeding only on the edge of the reserve, so my expectation that crop raiding by primates will occur in farms that are closer to the reserve was not supported. However, I found some evidence to suggest the potential of primates to raid crops based on their behaviour on the reserve edge. Feeding on the edge of the reserve was the most common behaviour for primates during the wet season as compared to the dry season. This was not surprising since during the wet season natural food is abundant inside the reserve, so it was inevitable that primates would decrease their travelling behaviour and increase their feeding behaviour during this season since they did not transgress the farm boundaries to raid crops. Interestingly, red colobus monkeys (*Procolobus kirkii*) showed a greater consumption of crops on the edge of coconut plantation as a prelude to raiding of coconuts (Siex & Struhsaker, 1999). Chacma baboons in Bossou, Guinea were found more frequently traveling than feeding during the dry season (Yamakoshi & Sugiyama, 1995). They decreased feeding and increased traveling because the density of fruit-food trees was low during the dry season, and thus they needed to travel longer distances to search for them (Yamakoshi & Sugiyama, 1995). Similar explanations might also apply to the vervet monkeys but supporting information is not available. Greater traveling might also be influenced by biotic factors. For example, (Isbell *et al.* 1998) females in larger vervet monkey groups were found to travel further and stopped to eat more often than females in smaller vervet groups.

Several studies have investigated the crop raiding behaviour of elephant especially in Africa (Dzingirai, 2003; Sitati *et al.*, 2003). The crop raiding behaviour of impala and nyala is not widely documented (Dzingirai, 2003; Mamo, 2015), although migrant farmers in the Zambezi Valley in Zimbabwe poached impala, arguing that wildlife raid their crops and that it is only fair that they should have their revenge by killing and, most importantly, eating such animals in return (Dzingirai, 2003). Sitati *et al.* (2003) reported that elephant crop raiding behaviour in Africa poses serious challenges to wildlife managers, local communities and elephants alike. In 2001 in Zimbabwe, over seven crop raiding elephants were shot in the Lusulu area of Binga by migrant farmers, and earlier, in 2000 and 1998, five and seven elephants were killed respectively because they were raiding migrant farms (Dzingirai, 2003). The farming community adjacent to the Bale Mountains National Park in Ethiopia suggested the culling of mountain nyala (*Tragelaphus buxtoni*) as a measure against crop damage and disease transmission, apparently because the nyala were responsible for much of the crop damage at night in these farms (Mamo, 2015).

Consistent with my prediction, I found that the highest level of crop damage occurred during the dry season as compared to the wet season. Osborn & Hill (2004) and Umetsu *et al*. (2006) suggested that lower quality and reduced availability of natural food between the wet and dry season encourages and can exacerbate crop raiding. Other studies have suggested an increase in crop raiding during the dry season as a result of decreased water availability in protected areas (Treves, 2008) and higher nutrient quality food available on farms compared to the surrounding natural vegetation (Mwakatobe *et al*., 2014; Pahad, 2011).

Crop type is known to influence the level of crop damage (Hill, 1997), as occurred in my study. Maize (*Zea mays*) experienced the highest level of crop damage compared to other crops, especially during the dry season. This was not surprising considering the high nutritional value of this crop (Hill, 1997). My findings concur with Hill (1997) who found that the level of crop damage in farms adjacent to protected areas was determined by the type of crops planted, damage causing animal species and seasonal variations. They also found higher levels of maize crop damage during drier seasons. There are also important factors, including the stage at which crops suffers damage and the diversity of animal species that will feed on it (Naughton-Treves, 1997). Maize is attacked at all stages of its development from the newly sown seed to the time when the cobs are mature (Hill, 2000). Since maize is the most frequently grown food crop in the farming community studied here and is a food security crop (Strum, 1994), the higher level of damage sustained shown in my study might not be solely because of the nutritional value of maize but also because of its local abundance.

Contrary to the hypothesis by Naughton-Treves (1997), I found that the level of crop damage by rodents, insects and birds was not correlated with distance from the reserve boundary. Consistent with my study, Pittiglio *et al.* (2014) also found that the impact of crop raiding in three villages in Tanzania did not appear to be consistently related to distance. In contrast, Saj *et al.* (2001) reported that the close proximity of farms to protected areas is a significant positive predictor of crop raiding in Uganda, and farms closer to forests were reported to receive more raids than those farther away from the forest.

In conclusion, rodents appeared to be the most important damage-causing agents in the farms considered in my study, although the low diversity of rodents captured in my study might have been due to the drought that was experienced during the study. Nonetheless, some important patterns were highlighted. During the dry season, when natural resources become scarce, rodents supplement their diets with cultivated crops, if available (Treves, 2008). Crops offer accessible and diverse resources (depending on the crop type is being cultivated). For example, Treves (2008) reported rodents utilising not only crops but also fruit grown and stored in granaries around villages in Pakistan mostly in the drier months compared to the wetter months. Even though many studies on crop raiding indicated that farms that are in close proximity to protected areas are more vulnerable to crop raiding (Hill *et al*., 2002; Naughton-Treves, 1997; Naughton-Treves *et al*., 1998), my study showed no distance relationship. Although no primate raiding was recorded during my study, the potential for increasing human–primate conflict throughout Africa is increasing (Hockings *et al*., 2009), and the attractiveness of farm crops to primates (from camera trap footage) indicates a high probability of future raids. It is crucial to gain a better understanding of the ecological determinants of primate crop-raiding. Investigations should incorporate more detailed nutritional analyses of cultivated foods consumed at different times of the year, and patterns and changes over longer periods of time. Future studies during periods with greater rainfall should be done to holistically capture the crop raiding behaviour of a range of wildlife, and provide an important comparison for the data obtained in my study, conducted during a drought.

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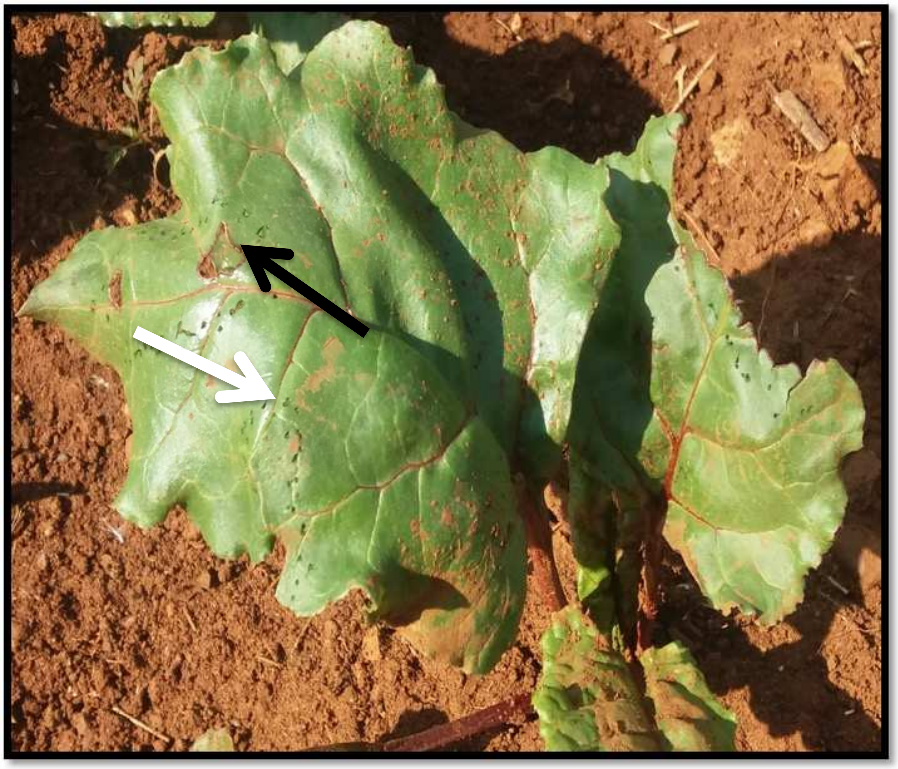
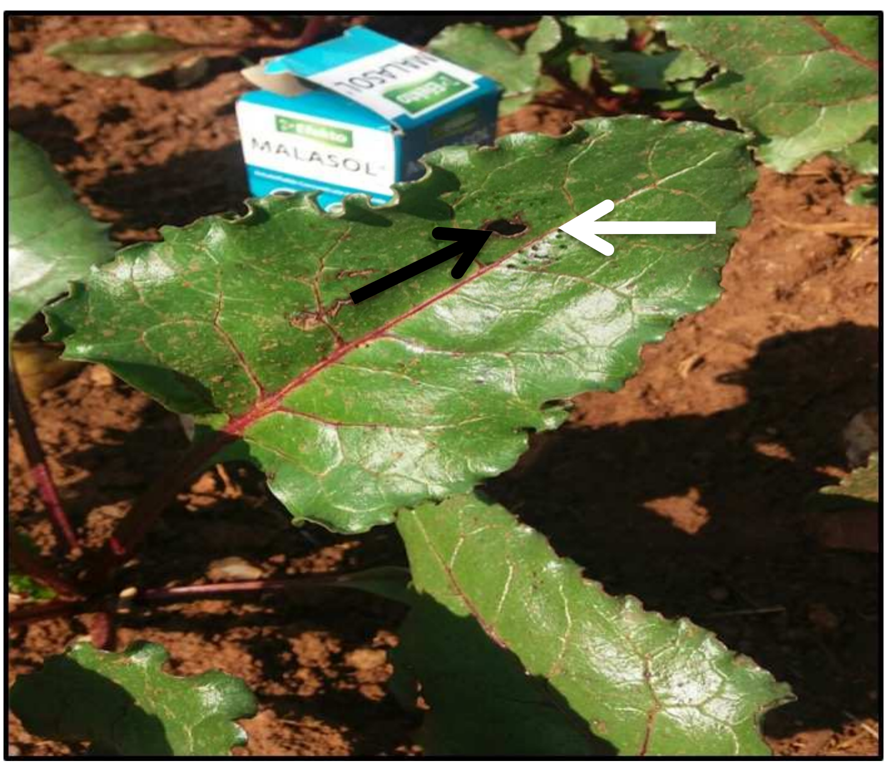
Supplementary material: **Photographs of some of the damaged food crops**

A: Spinach –damaged by insects

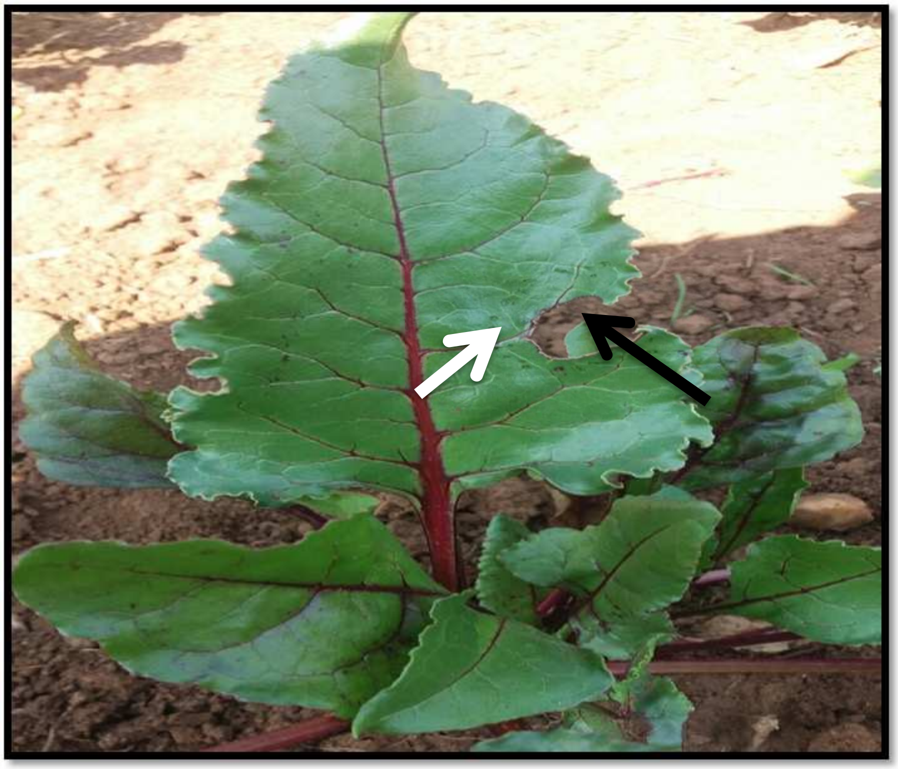
B: Spinach- damage by birds



C: Beetroot-damage by rodents



D: Beetroot-damaged by insects



E: Beetroot-damaged by birds

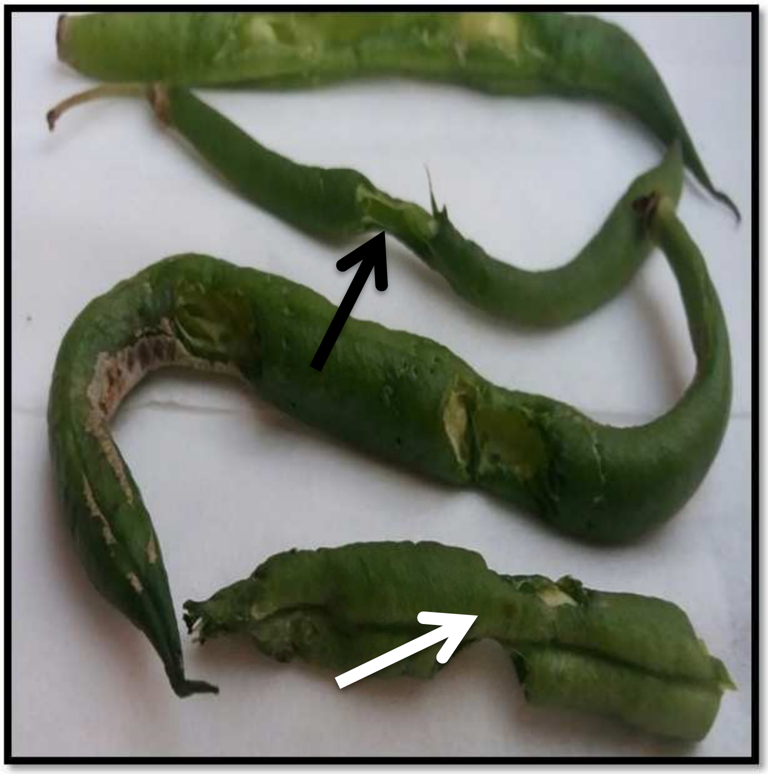
F: Cabbage damaged by rodents

G: Cabbage-damage by insects

H: Cabbage –damage by birds

I: Maize cob damaged by either rodents or birds

J: Common bean pods- damaged by insects



K: Common bean pod- damaged by rodents

Figure S1: Photographs of some of the sampling unit (leaves and/or seeds) of damaged crop types showing indentations used to identify crop-raiding animals. Photograph **A:** spinach (*Spinacia oleracea*) showing damage by insects, **B:** spinach showing damage by birds, **C:** beetroot (*Beta valgaris*) showing rodents bites, **D:** beetroot showing damage by insects with the box of the insecticide (Malasol) used by the farmers to control insects, **E:** beetroot showing damage by birds, **F:** cabbage (*Brassica oleracea*) showing rodent bite marks, **G:** cabbage showing damage by insects, **H:** cabbage showing damage by birds with evidence of birds droppings on one leaf, **I**: maize (*Zea mays*) cob damaged by either rodents/birds, **J:** common bean (*Phaseolus vulgaris*) pods damaged by insects, **K:** common bean pods showing damage by rodents. Specimen **I** and **J:** (on absorbent paper) were collected to use for another experiment (Chapter 3). Photographs show pinpricks (white arrows) around the destruction side to avoid pseudo sampling. Black arrows showing the damage area by rodents, insects and birds. (Photographs taken by the researcher in farms on the edge of Hluhluwe Game Reserve in South Africa).

The energy and income cost of crop raiding to subsistence homesteads abutting the Hluhluwe Game Reserve, South Africa

Abstract

Globally, crop raiding by wildlife affects farmers through the direct loss of food and income. Reduction of food quantity and loss of potential income are major concerns of subsistence farmers. I aimed to quantify seasonal variations in pre-and post-harvest energy loss and economic impact of crop raiding in a subsistence farming community alongside the Hluhluwe Game Reserve, South Africa. Twenty farms situated on the edge of the reserve were studied between April 2016 and March 2017. Crop damage by wildlife was quantified using a simple field-based system. The energy loss was measured by estimating the calories lost in kJ/g of four common crops: beetroot (*Beta vulgaris*), common bean (*Phaoseolus vulgaris*), maize (*Zea mays*) and spinach (*Spinacia oleracea*), which were damaged in all sampled farms. The energy of collected samples was later assessed using bomb calorimetry analyses. I assessed relative calorie loss by multiplying the calorific value of the crops by the level of damage values in the dry (April-September) and wet (March-August) seasons. The potential income loss was determined by multiplying the number of crop types (bunches/individual crops) damaged by the average local market cost of each individual crop type in South African Rand at an exchange rate of R13.43= US$1 in 2018 in the dry and wet seasons. The highest relative calorie loss was during the dry season as compared to the wet season, and this loss was the highest for maize compared to other crop types. Consistent with the relative calorie loss, the highest potential income loss was during the dry season for all crop types. Overall, I calculated the annual potential income loss as R2 427/annum (about US$180.71), for all crop types. The higher calorie loss for maize could impact subsistence farmers by reducing their daily calorie intake. Although the potential income loss appears trivial from an international perspective, this is a significant amount in an area where homestead income averages R15 000 (about US$1116. 90) per annum, and for the community whose economic capital is limited.

Keyword*s*: *crop raiding, economic loss, energy loss, livelihood, Zea mays*

Introduction

The literature on crop-raiding behaviour includes many accounts of wildlife entering farms and raiding crops (Hill *et al*., 2002; Hill & Wallace, 2012). This is often because farms near protected areas, such as nature reserves, often contain predictable, accessible and abundant sources of nutrition for wildlife (Treves, *et al*., 2009). Crop raiding behaviour creates conflict between people and wildlife, referred to as human-wildlife conflict (Hill, 2000). In particular, impoverished rural communities around protected areas are faced with the challenge of food shortages while they also have to deal with crop raiding (Chiyo & Archie, 2012). Crop raiding affects the food security of most subsistence homesteads in Africa's rural communities (Bariregа *et al*., 2010; Hill, 2000; Naughton-Treves *et al*., 1998). Thus, extensive damage through raiding can adversely impact farmers' lives and livelihoods (Wallace *et al*., 2012), compromise food security (Hill, 2000), reduce tolerance of wildlife (Naughton-Treves, 1997) and undermine wildlife management strategies (Hill, 2000).

Attempts have been made to quantify losses due to crop raiding (Barbehen *et al.*, 2004; Naughton-Treves *et al*., 1998; Parker *et al.*, 2008). However, most studies rely on information provided by farmers to quantify these losses (Naughton-Treves, 1997; Saj *et al.,* 2001; Warren *et al.*, 2007). Only a few studies have independently quantified the economic and nutritional cost of crop raiding to subsistence homesteads by taking measurements of damaged crops (Bareriga *et al*., 2010; Brashares *et al*., 2014). Moreover, the economic and nutritional losses are investigated separately (Hill, 2000; Naughton-Treves, 1997). Quantifying nutritional and economic losses will assist in determining the impact of crop raiding by wildlife on these marginalised communities, since crop raiding affects farmers through the direct loss of food (Hill, 2000; Siex & Struhsaker, 1999) and income (Butler, 2000; Holmern & Roskaft, 2013; Osborn & Parker, 2003).

Crop raiding and nutrition

Crop raiding reduces the amount of food available to a subsistence homestead (Rainer, 2002). Crop raiding as well as livestock depredation are some of the underlying factors behind the reduced daily nutritional intake for homesteads adjacent protected areas (Mkanda, 1994; Nahonyo, 2001; Naughton- Treves *et al*. 1998). McNeely & Scherr (2001) reported that in most parts of Africa, under-nutrition rates are higher in the vicinity of biodiversity hotspots than for the country as a whole partly because of crop raiding. Leatherman & Goodman (2005) concurred that crop raiding can contribute significantly to changes in diets that include increased dependency on purchased items and a decline in overall nutrition. Cernea & Schmidt-Soltau (2003) reported that rural populations living near protected areas have a lower nutritional state than other people from the same ethnic background, due to a significantly lower agricultural yield. Kaswamila *et al*. (2007) found that crop damage by wild animals from Mkomazi Game Reserve and Lake Manyara National Park in northern Tanzania was on average 0.08 tons per year, an equivalent of two months loss of homestead food. These losses subsequently result in reduced daily nutritional intake of these poor communities abutting protected areas (Kaswamila *et al*., 2007). Thus, crop damage contributes significantly to food insecurity (Mkanda, 1994; Nahonyo, 2001; Ntiamoa-Baidu, 1997; Naughton-Treves *et al*., 1998; Yudelman *et al*., 1998).

Crop raiding influences nutritional quality of diets indirectly in at least two ways. Firstly, crop raiding limits the range of crops that could be grown because some farmers plant less palatable, less nutritious crops (e.g. chillies) to reduce crop raiding in the place of nutritious crops (Sitati *et al*., 2005). In addition, Barering *et al*. (2010) found that homesteads adjacent to the Queen Elizabeth National Park in Uganda that experienced crop raiding had a lower dietary diversity index compared to those that did not experience crop raiding. Secondly, cash crops are damaged which would provide income for food to supplement existing diets (Boyd *et al*., 1999; Mkanda, 1994; Nahonyo, 2001; Ntiamoa-Baidu, 1997). Understanding the nutritional cost of crop raiding to rural subsistence farmers, however, remains largely understudied since most human-wildlife conflict studies usually focus on those losses suffered by commercial farmers (Dostaler *et al.*, 2011).

The economic impact of crop raiding

The economic impact of crop raiding on subsistence farming has been recorded in several studies (Hill, 2004; Khan, 1994; Naughton-Treves *et al*., 2005; Woodroffe *et al*., 2005). Studies have shown how African subsistence farmers have suffered loss due to crop raiding (Mturi, 1991; Saj *et al*., 1998; Sillero-Zubiri & Switzer, 2001). For example, in agricultural areas around the Maasai Mara Game Reserve in Kenya, crop raiding costs homesteads US$ 200-400 per year (Mkanda, 1994). In the Budongo Forest Reserve in Uganda, the cost of crop raiding and crop guarding (an incurred cost of raiding) was US$

96-519 per homestead per year (Hill, 1997). This is a huge amount if we consider average local salaries of people being only US$25-30 per month (Hill, 1997). Also, in Uganda, on the forest edge of Entebbe, several farmers suffered financial losses due to vervet monkey (*Chlorocebus pygerythrus*) crop-raiding, ranging from US$80 to US$400 per annum (Saj *et al*., 1998). Even if the amount of crop damage appears insignificant compared to overall food production, it is not insignificant to those farmers who have to bear the financial burden of crop loss (Ntiamoa-Baidu, 1997; Yudelman *et al*., 1998).

In this study, I aimed to quantify the seasonal variation in pre-and post-harvest calorie loss and the economic impact of crop raiding in a subsistence farming community near Hluhluwe Game Reserve in South Africa. Specifically, I collected damaged plant parts (mostly leaves and seeds) of different crops and assessed the relative calories lost due to crop damage by wildlife. I also surveyed local street vendors to obtain the "street value" in South African Rand to assess the economic impact of crop raiding by estimating income loss due to crop damage. I made two predictions. 1. I predicted that the relative calorie loss and income cost to farmers would be highest for maize compared to other damaged food crops. Maize is reported to be of higher nutritional value to crop raiding animals (Hill, 2002, 2012; Siex & Struhsaker, 1999). Hill (2002) also reported maize to be an important cash crop for most rural subsistence farmers. 2. I predicted that the potential income and relative calories lost would be highest during the dry season as compared to the wet season, since several studies reported higher levels of crop raiding during the dry season (Hill, 2002; Naughton-Treves *et al*., 1997; Siex & Struhsaker, 1999). In addition, the two hypotheses above were generated from the results of the previous study (Chapter 2).

Material and methods

Study site

I investigated pre- and post-harvest energy and economic loss in 20 subsistence farms at Phindisweni community (S 28°00' E 31°42'), adjacent to the Hluhluwe Game Reserve (S 28°26 E 32°09'; Figure 3.1) from April 2016 to March 2017. These farms were selected for study (with the assistance of two field assistants) based on their accessibility and because growing crops for homestead use is the primary mode of subsistence for these farmers. Various crops are cultivated locally, although individual farmers tend to concentrate on growing maize, common bean, spinach and beetroot in any growing season. Maize is the main source of carbohydrate and common beans are the major source of protein in the diet of the farmers and their homesteads.

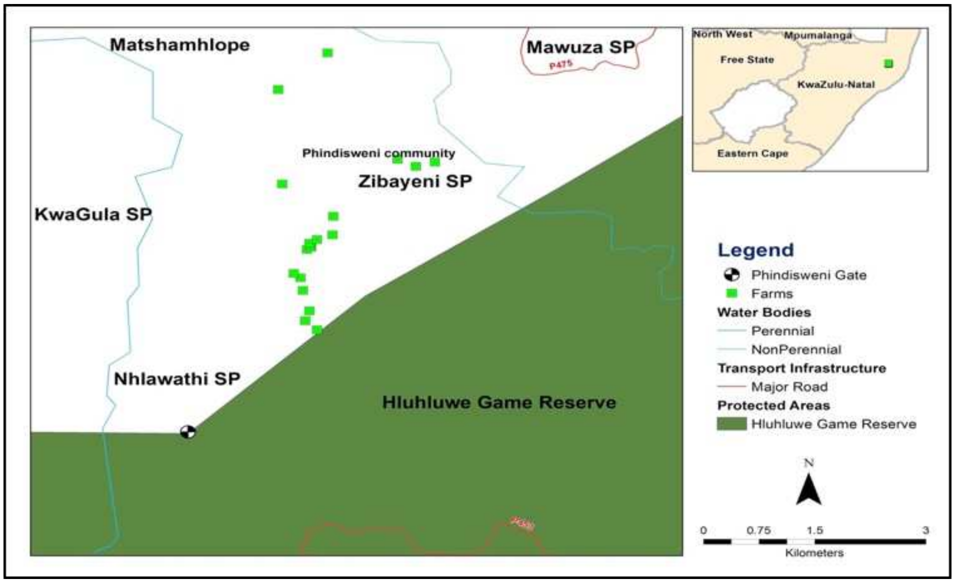


Figure 3.1. Map showing the location of Phindisweni community with the sampled farms (green squares), on the edge of Hluhluwe Game Reserve. Inset: Map of South Africa showing KwaZulu-Natal Province and the study site (green square).

The crop samples were collected inside quadrats. Several 1 m^2 quadrat were placed to cover at least 20% of the cultivated area for each farm (see Chapter 2). Quadrats were randomly placed flat on the ground in the farms and left lying there for 10 consecutive days each month throughout the study (see below). The joint ends of the quadrats were covered in bright insulation tape to locate the quadrats later. Most farmers planted their crops in rows (personal observation). Therefore, the quadrats were placed to cover all crop types planted per farm. I used 6 to 16 quadrants, depending on the size of the cultivated land in each farm. Crops that were damaged in the study were beetroot (*Beta vulgaris*), common bean (*Phaoseolus vulgaris*), maize (*Zea mays*) and spinach (*Spinacia oleracea*). I collected the leaves of crops because these were the most prominent parts of the crops damaged (details below) for beetroot and spinach (details below). Beetroot leaves were commonly used for relish in the study area. Moreover, during beetroot harvest there were no evidence of root damage. Damaged maize cob and common bean pods were also collected. A Garmin GPSMap62 handheld device was used to record several farm attributes, including the geographical location (GPS coordinates points of the farms) and aspect slope (in metres) of the central position of each of the 20 farms sampled. This was done to assess whether the slope of the farm influenced calorie values of crops on the farms. The surface area of each farm and the area cultivated were established by walking the perimeter of each sampled farm and cultivated land separately and calculating the approximate area in m^2.

Crop sampling

I visited the 20 farms for 10 consecutive days, twice a day (morning and evening) every month for the duration of the study to assess the amount of damage. Damaged crops were identified by using teeth marks, ragged breaks with shredded edges and holes caused by rodents, round holes on the leaves by insects, and tears off the food crops by birds (Chapter 2). Crop damage was quantified by counting the total number of damaged individual crop samples (i.e. whole leaves of beetroot, spinach and seeds of maize and common bean) in each quadrat inside each quadrat in the 20 sampled farms and obtained the total number of damaged crops in each sampled farm.

Overall, I collected a total of 4465 damaged individual crop samples. I chose to collect and analyse the damaged parts since these were the parts selected by crop raiders. The individual samples were transported within 10 minutes to the Hluhluwe Game Reserve research centre laboratory, where I washed them with distilled water to remove excess dirt and dried them on absorbent paper (Thrupp, 2000). The samples were weighed on Mettler Toledo® - XPE4001S – Precision Balance and recorded as a wet mass in grams to 2 decimal places. All samples were then air-dried for two days in 10 g brown paper bags and later oven-dried at 65°C for 16 hours overnight in the Ecotherm™ Labotech laboratory drying oven. The mass of the dry samples was re-recorded. After oven drying, the samples were ground into powder using an unpolished granite mortar and pestle and then stored in plastic Ziploc bags labelled with the farm number, plant type, quadrat number and collection date. The samples in their powder form were then transported later to the Metallurgy Engineering laboratory of the University of Johannesburg for calorific analysis.

To quantify post-harvest nutritional loss, I surveyed the 20 sampled farms stores to collect stored food crops. However, none of the sampled farms had food crops stored during the study because of the drought in 2015/16. Therefore, I did not quantify post-harvest nutritional loss.

Determination of calories

Powdered samples were placed in sterile beakers (250 ml) labelled with the farm number and the sample name. The labelled samples were then oven dried at 150°C for 2 hours in an Ecotherm™ Labotech laboratory drying oven to remove moisture and to improve complete burning during calorific analysis. Powdered crop samples were transferred to a crucible on a Sartorius balance to weigh ~ 0.5g or less of each sample using a stainless steel laboratory spatula. The number of samples burned per individual sampling unit depended on the dry mass of each sample, and ranged from 55.51g to 121.41g for beetroot, 93.93g to 173.28g for common bean seed pods, 100.69g to 205.52g for maize seeds and 42.16g to 97.67g for spinach. A fully automatic e2k combustion oxygen bomb calorimeter (Parr Instrument Company, USA) was utilised to obtain calorific values of the collected crop samples. The oxygen flow into the calorimeter was set at 300 atm. The calorific values in kJ/g were recorded to two decimal places per sample bombed for further data analysis.

Energy loss

I estimated potential energy loss by multiplying the calorific values obtained from the bomb calorimetry analyses by the proportion of the level of damage values (obtained by dividing the level of damage for all crops sampled in a farm by the total number of individual crops in a quadrant; separate analyses were conducted for dry and wet seasons For example, the potential energy loss (Relative calorie loss in Supplementary material: Table. S1) for beetroot during the dry season for farm number 1 was 0.2 proportion of the level of damage, calculated as follows:

Relative calorie loss = proportion of the level of damage* calorific value (kJ/g)

Relative calorie loss = 0.2*496 KJ/g = 99.2 KJ/g (See also **supplementary material: Table. S1**).

Income loss

To investigate the economic impact of crop raiding, I estimated the potential income loss incurred due to damage of beetroot, common bean, maize and spinach. I used the number of damaged crop types to determine the loss in monetary value. I obtained the average price cost of different crop types from the street vendors around Hluhluwe Game Reserve. The costs differed by crop type: for beetroot, common bean and spinach, I used the cost of 1 bunch since that is how the street vendors and the local fresh produce market sell these three crops. In addition, I recorded the average number of leaves for 1 bunch of spinach, beetroot and the average number of common bean pods for 1 bunch of common beans from the street vendors. I found that 1 bunch of spinach and beetroot consisted of an average of 13 leaves and 1 bunch of common beans had ~47 individual pods on average. Similar values were reported by others (Blair *et al*., 2003 & Rondon *et al*., 2007; Singh *et al.*, 1991). To determine the potential income loss, I multiplied the number of damaged crop type bunches (obtained by dividing the average number of leaves/pods per bunch by the level of damage) by the average cost value (R) of these individual crops. For example, the potential income loss for beetroot during the dry season for farm number 1 was calculated as follows:

Potential income loss = Number of damaged crop type bunches*Average cost value (R)

Potential income loss for 2 bunches = 2*R14 = R28. (See also **supplementary material:** Table S2).

To estimate the number of maize cobs damaged in each farm, I determined the number of cobs that lost seeds and could not be sold (information provided by the farmers). The potential income loss value for maize was obtained by multiplying the number of damaged maize crops by the average costs value (R) in the dry and wet seasons of maize in South African Rand at an exchange rate of (R13.43 = US$1) in 2018 obtained from street vendors. The costs differed seasonally across all crop types (**Supplementary material:** Table S2).

Statistical analyses

All statistical analyses were done using R statistical software (version 3.3.3, 2017). Statistical tests were two-tailed, and significance levels were set at $P \leq 0.05$. Data did not meet the assumptions of normality (Shapiro-Wilk test), so I used nonparametric statistical tests. I applied Generalized linear mixed (GLMM, *glmer* function and a Poisson distribution; lme4 package; Bates *et al*. 2015) models to assess the potential nutritional and economic cost to farmers. For each GLMM applied one category was set as a reference, to which others were compared to analyse the data. For each month, data were combined to obtain the values of measurements for all the variables (level of damage, calorific values and costs of damaged crop types) seasonally.

To investigate energy and economic cost to farmers due to crop raiding, I compared relative calorie loss and income loss by crop types for beetroot, common bean, maize and spinach in the dry and wet seasons. The relative calorie loss and potential income loss were analysed separately as response variables, crop type, season and the interaction between crop type and season were set as predictor variables. For both models, I included farm size as a random factor (intercepts only) to account for the potential farm size effect. The potential income and relative calorie loss could be influenced by the size of the farms planted since most farms had to reduce the area ploughed to avoid losing crops should the drought have persisted (personal communication with farmers). I checked the model fit for the variables described above, and used the most appropriate model, based on the plot of the residuals against the fitted values from each model (Crawley, 2007). I included season, crop type and two-way interactions of season*crop type as explanatory variables for both models. I generated P values using likelihood ratio tests (Bates *et al.* 2015). In analysing relative calorie loss, I included the slope of the farms as a continuous predictor variable to ascertain whether slope influences the relative calorie loss. Accordingly, a nonparametric procedure, the Spearman's rank order correlation coefficient (i.e. Spearman's rho) was also performed to investigate the relationship between the relative calorie loss for individual crop types and farm slopes.

For all models, significance was determined using Wald (χ^2) statistics. All graphs were produced using a GGplot2 package from the R software.

Results

Levels of calories

Damaged crop parts of beetroot, common bean, maize and spinach were collected in 20 sampled farms and bombed. The calorific values were higher during the dry season (16001.79kJ/g) than the wet season (14777.2 kJ/g) for all crop types bombed (**Supplementary material:** Table S1). Higher levels of calories were recorded for maize (17069.54kJ/g) followed by common bean (8387.36 kJ/g) spinach (3576.95 kJ/g) and beetroot (1745.14 kJ/g; **Supplementary material:** Table S1).

Variations in relative calorie loss

Season (Wald $\chi^2_1 = 48.15$, $P < 0.001$), crop type (Wald $\chi^2_3 = 14193.01$, $P < 0.001$) and the interaction between season and crop type (Wald $\chi^2_3 = 220.63$, $P < 0.001$) were significant predictors of relative calorie loss. Significantly higher relative calorie loss occurred during the dry season as compared to the wet season and the highest relative calorie loss was for maize followed by common bean, spinach and beetroot. The highest relative calorie loss for maize and common bean occurred during the dry season as compared to the wet season, but the highest relative calorie loss for spinach and beetroot was during the wet season as compared to the dry season (Figure 3.2). Farm slope did not affect the relative calorie loss (Wald $\chi^2_1 = 0.22$, $P = 0.633$).

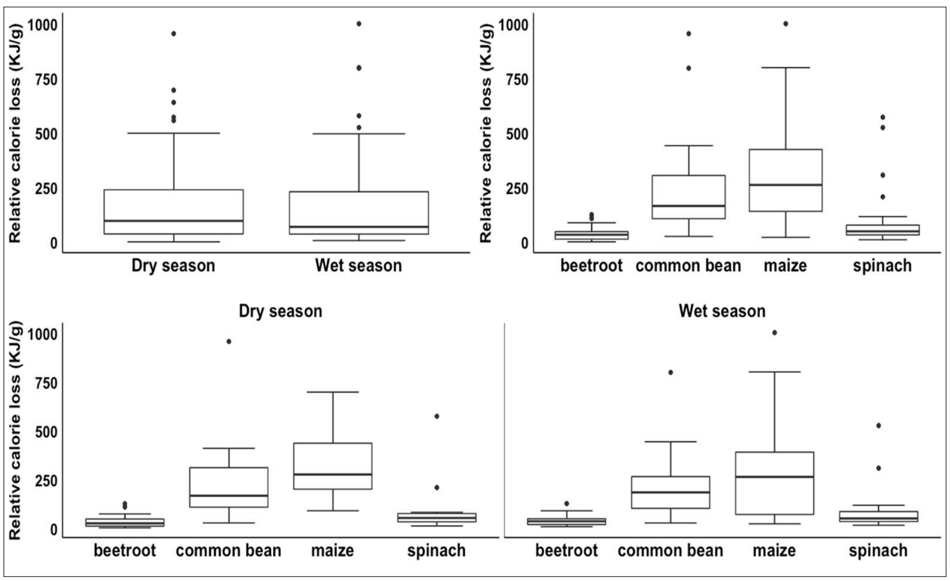


Figure 3.2. Relative calorie loss by season (top left), crop type (top right) and the interaction between season and crop type (bottom) experienced by farmers on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and dots outside of boxes indicate outliers.

Prices of different crop types

Prices of beetroot, common bean, maize and spinach during the dry and wet season were obtained from street vendors a few kilometres from the Hluhluwe Game Reserve. The average cost of 1 bunch of beetroot during the dry season was R14.00 and R12.00 during the wet season. The average cost of 1 bunch of spinach was R10.00 during the dry season and R7.00 during the wet season. Common bean was sold in bunches by the street vendors, and cost R15.00 during the dry season and R13.00 during the wet season. Maize (1 cob) was sold for R11.00 during the dry season and R10.00 during the wet season (see **Supplementary material**: Table S2).

Seasonal variations in potential income losses by crop type

Season (Waldχ^2_1 = 166.06, P < 0.001), crop type (Wald χ^2_3 = 274.36, P < 0.001) and the interaction between season and crop type (Waldχ^2_3 = 43.79, P < 0.001) were significant predictors of the potential income loss. Significantly higher potential income loss was incurred during the dry season as compared to the wet season. The highest potential income loss was for spinach followed by beetroot and maize during the dry season as compared to the wet season. All sampled farms experienced some level of damage for all or most crops, and based on the calculation of the potential income loss used in this study (See methods above; **Supplementary material**: Table S2), the potential income loss ranged from R0.00-R60.00. The range represented whether or not crops could be potentially salvaged for sale (e.g. one leaf only being attacked vs the whole crop). The potential income loss for common bean was higher during the wet season as compared to the dry season (Figure 3.3). Overall, the potential income loss in this study ranged from R0.00-R60.00 for spinach, R0.00-R56.00 for beetroot, R0.00-R41.00 for maize and R0.00-R18.00 for common bean across all seasons (Figure 3.3). Using the data in **Supplementary material** in Table S2, I calculated that the potential income loss for all farms per annum was R2 427.00 (about US$ 180.71) at an average of R77.35 (SD = R123.83) per farm in the dry season as compared a mean of R 44 (SD = R 71. 179) in the wet season.

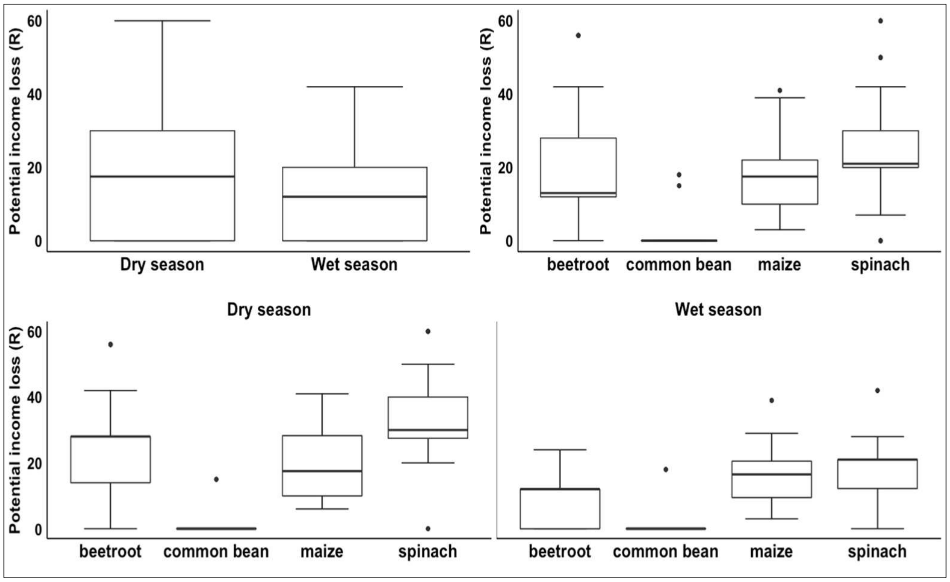


Figure 3.3. Potential income loss by season (top left), crop type (top right) and the interaction between season and crop type (bottom) experienced by farmers on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and dots outside of boxes indicate outliers.

Discussion

I investigated the energy and potential economic impact of crop raiding on subsistence homesteads abutting the Hluhluwe Game Reserve. Several studies on human-wildlife-conflict have investigated economic or nutritional impacts (Siex & Struhsaker, 1999; Hill, 2000; Naughton-Treves, 1997) of crop raiding on subsistence farmers adjacent to protected areas. However, I am not aware of any studies that have investigated these aspects in one study. I calculated higher relative calorie loss during the dry season as compared to the wet season and the highest calorie loss was for maize as compared to other food crops, consistent with my predictions.

Most studies of nutritional loss due to crop raiding focus on analysing the nutrient composition of crop types (Chiyo *et al.*, 2005; Kabigumila, 1993; Ruggiero, 1992). Naughton-Treves (1998) reported that crops raided at Kibale National Park contained higher fibre during months of higher rainfall. Yet, higher levels of crop damage and nutrient loss for farmers were recorded in the drier seasons (Naughton-Treves *et al.*, 1998) consistent with my study. The higher nutrient/calorie loss in the dry season has been reported in several studies (Chiyo *et al*, 2005; Dudley *et al*., 1992; Nyhus & Tilson, 2000; Rode *et al*., 2006). During the dry season, the frequency of crop raiding was related to higher nutrient contents of cultivated crops at Way Kambas National Park in Sumatra (Nyhus *et al*., 2000). Rode *et al*. (2006) also reported that the lack of sodium in natural diets drove elephants (*Loxodonta africana*) of Kibale National Park in Uganda to raid crops during the dry season. It is most likely a consequence of crop raiders targeting better quality agricultural crops over natural food. In particular, food crops are highly digestible, high in energy and low in secondary compounds compared to natural food (Dierenfeld, 1994; Hill, 2000; Nyhus & Tilson, 2000).

There may be two explanations for the greater relative calorie loss for maize compared to other crop types. Firstly, the level of damage for maize was highest compared to other crops in my study. Therefore, the higher relative calorie loss for maize is most likely attributable to the higher levels of damage. Secondly, previous research has reported that maize is high in nutrients (Calenge *et al*. 2004; Genov & Massei, 1995; Hill, 2000; Naughton-Treves, 1997), and has higher energy than other crops (Schley & Roper, 2003). Treves (1998) reported that maize (ripe and dried) was the most frequently eaten crop by animal crop raiders in West Africa because of its nutritional value.

The highest potential income loss was during the dry season, consistent with my prediction. This was not surprising since the highest level of crop damage recorded in my study was during the dry season, and the prices of crops were higher in the dry than the wet season. The literature on seasonal variation in the economic impact of crop raiding on subsistence farming communities is limited, and instead annual loss is reported. It should be noted that the income loss in my study does not necessarily mean loss of cash revenue, because the homesteads consumed most of their crops rather than selling them. Rather, it is used in a similar sense to “direct use value” of agricultural goods in the livelihoods literature (Shackleton *et al*., 2007). In the case of those farmers who consume their own crops, the income loss from crop damage is a metric of the cost to them if they have had to purchase crops to replace what was lost in order to maintain their food consumption (Shackleton *et al*., 2007).

On the forest edge of Entebbe, Uganda, several farmers suffered financial losses due to vervet monkey (*Chlorocebus pygerythrus*) crop-raiding, ranging from US$80 to US$400 per annum (Saj *et al*., 1998).

I calculated a potential income loss of R2 427.00 (about US$ 180.71) per annum for all crop types combined. This amount appears trivial from an international perspective but it is a significant amount in an area where homestead income average is R15 000 per annum (US$ 1116.90; StatsSA, 2011). I found the highest potential income loss to be for spinach, despite the highest level of damage for maize. This finding was surprising considering the low street vendor cost and the lowest level of damage of this crop as compared to other crops (**Supplementary material: Table** S2). This finding is also in contrast to many studies that reported higher potential income cost to farmers for maize due to crop raiding (Heinen, 1993; Naughton-Treves *et al*., 1998; Newmark *et al*., 1994; Parry & Campbell, 1992; Studsrod & Wegge, 1995). However, most of these studies have quantified damage based on questionnaire surveys rather than measurement of the level of crop damage considered in my study.

In conclusion, I adopted a unique approach by measuring both crop damage and then calculating potential energy and income loss in a subsistence farming community. Mine is the first study to measure these impacts in such communities in South Africa. Despite the small number of farms studied, my findings suggest that crop raiding by wildlife could reduce annual calorie intake and incur potential income loss of farming homesteads adjacent to the Hluhluwe Game Reserve. The impact was greater in the dry season. My findings must be viewed against the 2015/2016-drought season when I conducted my study. While the drought might have encouraged crop raiding by wildlife, the quantity and quality of crops available for raiding would have been reduced. Importantly, crop raiding in my study was largely conducted by micro-fauna (rodents, birds and insects). The impact of larger fauna, such as primates and large herbivores, are likely to be greater, both nutritionally and economically. It is difficult to predict whether a lack of such impact was due to environmental (drought) conditions or effective deterrents by farmers. Therefore, future studies of crop raiding must be conducted over longer periods under various environmental conditions. Finally, my metrics of energy and income losses must be considered as only potential outcomes. While my approach was unique (i.e. measuring damage and calculating potential loss), the resourcefulness of the subsistence farming community in overcoming such potential losses must be considered in future studies.

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Supplementary material Table S1. Relative calories loss index for damaged beetroot, common bean, maize and spinach due to crop raiding during the dry and wet seasons. The relative calorie loss is calculated as the average level of damage multiplied by the calorific value (kJ/g).

Farm #	Farm slope (m)	Crop type	Season	[1]Level of damage	[2]Total number of individual crops	[3]Proportion of the level of damage	[4]Calorific values (KJ/g)	[5]Relative calorie loss
1	401	Beetroot	dry season	32	157	0.2	496	99.2
2	434	Beetroot	dry season	28	75	0.37	240	89.6
3	434	Beetroot	dry season	23	150	0.15	238	36.49
4	434	Beetroot	dry season	52	155	0.34	145	48.65
5	434	Beetroot	dry season	37	130	0.28	245	69.73
6	456	Beetroot	dry season	17	112	0.15	179	27.17
7	456	Beetroot	dry season	14	50	0.28	116	32.48
8	456	Beetroot	dry season	47	150	0.31	151	47.31
9	456	Beetroot	dry season	9	120	0.08	268	20.1
10	456	Beetroot	dry season	18	120	0.15	178	26.7
11	456	Beetroot	dry season	11	120	0.09	89	8.16
12	456	Beetroot	dry season	27	120	0.23	142	31.95
13	456	Beetroot	dry season	25	130	0.19	310	59.62
14	456	Beetroot	dry season	37	185	0.2	302	60.4
15	456	Beetroot	dry season	26	155	0.17	286	47.97
16	456	Beetroot	dry season	14	155	0.09	130	11.74
17	466	Beetroot	dry season	6	124	0.05	171	8.27

18	466	Beetroot	dry season	19	135	0.14	241	33.92
19	466	Beetroot	dry season	38	187	0.2	179	36.37
20	401	Beetroot	dry season	7	125	0.06	683	38.25
1	401	Beetroot	wet season	18	127	0.14	447	63.35
2	434	Beetroot	wet season	22	75	0.29	491	144.03
3	434	Beetroot	wet season	47	145	0.32	247	80.06
4	434	Beetroot	wet season	33	134	0.25	201	49.5
5	434	Beetroot	wet season	13	110	0.12	209	24.7
6	456	Beetroot	wet season	18	112	0.16	301	48.38
7	456	Beetroot	wet season	16	50	0.32	119	38.08
8	456	Beetroot	wet season	9	130	0.07	115	7.96
9	456	Beetroot	wet season	16	120	0.13	258	34.4
10	456	Beetroot	wet season	10	120	0.08	209	17.42
11	456	Beetroot	wet season	14	118	0.12	279	33.1
12	456	Beetroot	wet season	18	118	0.15	114	17.39
13	456	Beetroot	wet season	21	150	0.14	194	27.16
14	456	Beetroot	wet season	18	147	0.12	94	11.51
15	456	Beetroot	wet season	13	123	0.11	130	13.74
16	456	Beetroot	wet season	6	123	0.05	182	8.88
17	466	Beetroot	wet season	18	124	0.15	298	43.26
18	466	Beetroot	wet season	26	135	0.19	281	54.12
19	466	Beetroot	wet season	9	138	0.07	551	35.93
20	401	Beetroot	wet season	126	288	0.44	357	156.19

1	401	common bean	dry season	32	115	0.28	910	253.22
2	434	common bean	dry season	38	150	0.25	906	229.52
3	434	common bean	dry season	46	145	0.32	572	181.46
4	434	common bean	dry season	32	100	0.32	626	200.32
5	434	common bean	dry season	17	140	0.12	568	68.97
6	456	common bean	dry season	8	130	0.06	2380	146.46
7	456	common bean	dry season	14	50	0.28	912	255.36
8	456	common bean	dry season	17	75	0.23	441	99.96
9	456	common bean	dry season	16	30	0.53	578	308.27
10	456	common bean	dry season	17	30	0.57	573	324.7
11	456	common bean	dry season	22	134	0.16	1198	196.69
12	456	common bean	dry season	17	130	0.13	441	57.67
13	456	common bean	dry season	50	30	1.67	574	956.67
14	456	common bean	dry season	37	117	0.32	414	130.92
15	456	common bean	dry season	41	110	0.37	939	349.99
16	456	common bean	dry season	11	98	0.11	1013	113.7
17	466	common bean	dry season	7	40	0.18	935	163.63
18	466	common bean	dry season	19	91	0.21	801	167.24
19	466	common bean	dry season	23	100	0.23	1200	276
20	401	common bean	dry season	16	130	0.12	913	112.37
1	401	common bean	wet season	7	65	0.11	1082	116.52
2	434	common bean	wet season	18	60	0.3	1166	349.8
3	434	common bean	wet season	18	45	0.4	1028	411.2

4	434	common bean	wet season	8	40	0.2	603	120.6
5	434	common bean	wet season	11	32	0.34	915	314.53
6	456	common bean	wet season	8	30	0.27	796	212.27
7	456	common bean	wet season	13	46	0.28	801	226.37
8	456	common bean	wet season	9	25	0.36	632	227.52
9	456	common bean	wet season	7	30	0.23	345	80.5
10	456	common bean	wet season	7	30	0.23	231	53.9
11	456	common bean	wet season	16	53	0.3	1483	447.7
12	456	common bean	wet season	6	30	0.2	343	68.6
13	456	common bean	wet season	25	70	0.36	432	154.29
14	456	common bean	wet season	28	135	0.21	679	140.83
15	456	common bean	wet season	16	110	0.15	918	133.53
16	456	common bean	wet season	13	123	0.11	1396	147.54
17	466	common bean	wet season	14	46	0.3	1138	346.35
18	466	common bean	wet season	16	91	0.18	211	37.1
19	466	common bean	wet season	7	54	0.13	864	112
20	401	common bean	wet season	14	134	0.1	891	93.09
1	401	Maize	dry season	165	698	0.24	612	144.67
2	434	Maize	dry season	370	494	0.75	565	423.18
3	434	Maize	dry season	240	730	0.33	445	146.3
4	434	Maize	dry season	263	630	0.42	1095	457.12
5	434	Maize	dry season	82	478	0.17	559	95.9
6	456	Maize	dry season	153	280	0.55	572	312.56

7	456	Maize	dry season	265	436	0.61	1167	709.3
8	456	Maize	dry season	90	582	0.15	555	85.82
9	456	Maize	dry season	84	216	0.39	815	316.94
10	456	Maize	dry season	95	218	0.44	1233	537.32
11	456	Maize	dry season	84	202	0.42	1122	466.57
12	456	Maize	dry season	131	198	0.66	839	555.1
13	456	Maize	dry season	315	532	0.59	972	575.53
14	456	Maize	dry season	256	828	0.31	449	138.82
15	456	Maize	dry season	168	643	0.26	1148	299.94
16	456	Maize	dry season	110	578	0.19	673	128.08
17	466	Maize	dry season	185	390	0.47	1123	532.71
18	466	Maize	dry season	335	436	0.77	1676	1287.75
19	466	Maize	dry season	93	582	0.16	1335	213.32
20	401	Maize	dry season	52	228	0.23	1006	229.44
1	401	Maize	wet season	219	390	0.56	867	486.85
2	434	Maize	wet season	290	856	0.34	818	277.13
3	434	Maize	wet season	216	526	0.41	1290	529.73
4	434	Maize	wet season	143	226	0.63	1181	747.27
5	434	Maize	wet season	118	278	0.42	1016	431.25
6	456	Maize	wet season	220	434	0.51	806	408.57
7	456	Maize	wet season	199	336	0.59	1096	649.12
8	456	Maize	wet season	126	382	0.33	691	227.92
9	456	Maize	wet season	80	200	0.4	885	354

10	456	Maize	wet season	100	146	0.68	795	544.52
11	456	Maize	wet season	50	198	0.25	681	171.97
12	456	Maize	wet season	73	166	0.44	1220	536.51
13	456	Maize	wet season	385	712	0.54	664	359.04
14	456	Maize	wet season	200	428	0.47	462	215.89
15	456	Maize	wet season	188	213	0.88	1026	905.58
16	456	Maize	wet season	50	178	0.28	812	228.09
17	466	Maize	wet season	187	370	0.51	1123	567.57
18	466	Maize	wet season	195	236	0.83	1426	1178.26
19	466	Maize	wet season	123	382	0.32	1165	375.12
20	401	Maize	wet season	30	188	0.16	1371	218.78
1	401	Spinach	dry season	50	98	0.51	412	210.2
2	434	Spinach	dry season	75	321	0.23	323	75.47
3	434	Spinach	dry season	35	110	0.32	237	75.41
4	434	Spinach	dry season	47	123	0.38	153	58.46
5	434	Spinach	dry season	6	100	0.06	406	24.36
6	456	Spinach	dry season	33	150	0.22	307	67.54
7	456	Spinach	dry season	39	100	0.39	149	58.11
8	456	Spinach	dry season	37	125	0.3	168	49.73
9	456	Spinach	dry season	32	140	0.23	58	13.26
10	456	Spinach	dry season	32	132	0.24	347	84.12
11	456	Spinach	dry season	22	140	0.16	90	14.14
12	456	Spinach	dry season	42	138	0.3	138	42

13	456	Spinach	dry season	77	150	0.51	155	79.57
14	456	Spinach	dry season	48	154	0.31	92	28.68
15	456	Spinach	dry season	63	123	0.51	160	81.95
16	456	Spinach	dry season	38	123	0.31	139	42.94
17	466	Spinach	dry season	53	130	0.41	90	36.69
18	466	Spinach	dry season	63	173	0.36	117	42.61
19	466	Spinach	dry season	28	124	0.23	128	28.9
20	401	Spinach	dry season	180	249	0.72	799	577.59
1	401	Spinach	wet season	45	150	0.3	234	70.2
2	434	Spinach	wet season	50	104	0.48	165	79.33
3	434	Spinach	wet season	25	146	0.17	151	25.86
4	434	Spinach	wet season	28	154	0.18	202	36.73
5	434	Spinach	wet season	4	56	0.07	241	17.21
6	456	Spinach	wet season	22	56	0.39	180	70.71
7	456	Spinach	wet season	56	100	0.56	199	111.44
8	456	Spinach	wet season	18	43	0.42	224	93.77
9	456	Spinach	wet season	22	130	0.17	180	30.46
10	456	Spinach	wet season	35	138	0.25	185	46.92
11	456	Spinach	wet season	25	135	0.19	212	39.26
12	456	Spinach	wet season	33	138	0.24	146	34.91
13	456	Spinach	wet season	73	180	0.41	205	83.14
14	456	Spinach	wet season	47	152	0.31	165	51.02
15	456	Spinach	wet season	37	137	0.27	185	49.96

16	456	Spinach	wet season	37	122	0.3	1759	533.47
17	466	Spinach	wet season	42	130	0.32	164	52.98
18	466	Spinach	wet season	37	73	0.51	234	118.6
19	466	Spinach	wet season	27	145	0.19	165	30.72
20	401	Spinach	wet season	208	360	0.58	534	308.53

[1]Level of damage=the sum of damaged individual crop parts per quadrat, in each farm

[2]Total number of crops =obtained from counting the number of individual crops in each quadrat per farm

[3]Proportion of the level of damage=level of damage/total number of crops in a quadrant

[4]Calorific values= values obtained from burning the samples on the ek2 bomb calorimeter (total for each farm sampled)

[5]Relative calorie loss=proportion of the level of damage* calorific value (kJ/g)

Table S2. Potential income loss index for beetroot, common bean, maize and spinach due to crop raiding during the dry and wet season. The potential income loss is calculated as the number of damaged food crop types multiplied by the average costs (R)

Farm #	Farm size (m2)	Crop type	Season	[1]Level of damage	[2]Average number of leaves/seeds per bunch	[3]Estimates of the number of individual corn cob damaged	[4]Number of damaged crop type (bunches /individual crop type)	[5]Average cost (R)	[6]Potential income loss (R)
1	800	Beetroot	dry season	32	13	n/a	2	14	28
2	7878	Beetroot	dry season	28	13	n/a	2	14	28
3	8112	Beetroot	dry season	23	13	n/a	2	14	28
4	2511	Beetroot	dry season	52	13	n/a	4	14	56
5	2759	Beetroot	dry season	37	13	n/a	3	14	42
6	900	Beetroot	dry season	17	13	n/a	1	14	14
7	900	Beetroot	dry season	14	13	n/a	1	14	14
8	240	Beetroot	dry season	47	13	n/a	4	14	56
9	1200	Beetroot	dry season	9	13	n/a	1	14	14
10	600	Beetroot	dry season	18	13	n/a	1	14	14
11	11160	Beetroot	dry season	11	13	n/a	1	14	14
12	900	Beetroot	dry season	27	13	n/a	2	14	28
13	900	Beetroot	dry season	25	13	n/a	2	14	28
14	900	Beetroot	dry season	37	13	n/a	3	14	42
15	900	Beetroot	dry season	26	13	n/a	2	14	28

16	900	Beetroot	dry season	14	13	n/a	1	14	14
17	3600	Beetroot	dry season	6	13	n/a	0	14	0
18	3000	Beetroot	dry season	19	13	n/a	1	14	14
19	30000	Beetroot	dry season	38	13	n/a	2	14	28
20	3600	Beetroot	dry season	7	13	n/a	0	14	0
1	800	Beetroot	wet season	18	13	n/a	1	12	12
2	7878	Beetroot	wet season	22	13	n/a	1	12	12
3	8112	Beetroot	wet season	33	13	n/a	2	12	24
4	2511	Beetroot	wet season	13	13	n/a	1	12	12
5	2759	Beetroot	wet season	18	13	n/a	1	12	12
6	900	Beetroot	wet season	16	13	n/a	1	12	12
7	900	Beetroot	wet season	9	13	n/a	0	12	0
8	240	Beetroot	wet season	16	13	n/a	0	12	0
9	1200	Beetroot	wet season	10	13	n/a	0	12	0
10	600	Beetroot	wet season	14	13	n/a	1	12	12
11	11160	Beetroot	wet season	18	13	n/a	1	12	12
12	900	Beetroot	wet season	21	13	n/a	1	12	12
13	900	Beetroot	wet season	18	13	n/a	1	12	12
14	900	Beetroot	wet season	13	13	n/a	1	12	12
15	900	Beetroot	wet season	6	13	n/a	0	12	0
16	900	Beetroot	wet season	18	13	n/a	1	12	12
17	3600	Beetroot	wet season	26	13	n/a	2	12	24
18	3000	Beetroot	wet season	9	13	n/a	0	12	0

19	30000	Beetroot	wet season	9	13	n/a	0	12	0
20	3600	Beetroot	wet season	32	47	n/a	0	15	0
1	800	common bean	dry season	38	47	n/a	0	15	0
2	7878	common bean	dry season	46	47	n/a	0	15	0
3	8112	common bean	dry season	32	47	n/a	0	15	0
4	2511	common bean	dry season	17	47	n/a	0	15	0
5	2759	common bean	dry season	8	47	n/a	0	15	0
6	900	common bean	dry season	14	47	n/a	0	15	0
7	900	common bean	dry season	17	47	n/a	0	15	0
8	240	common bean	dry season	16	47	n/a	0	15	0
9	1200	common bean	dry season	17	47	n/a	0	15	0
10	600	common bean	dry season	22	47	n/a	0	15	0
11	11160	common bean	dry season	17	47	n/a	0	15	0
12	900	common bean	dry season	50	47	n/a	1	15	15
13	900	common bean	dry season	37	47	n/a	0	15	0
14	900	common bean	dry season	41	47	n/a	0	15	0
15	900	common bean	dry season	11	47	n/a	0	15	0
16	900	common bean	dry season	7	47	n/a	0	15	0
17	3600	common bean	dry season	19	47	n/a	0	15	0
18	3000	common bean	dry season	23	47	n/a	0	15	0
19	30000	common bean	dry season	16	47	n/a	0	15	0
20	3600	common bean	dry season	7	47	n/a	0	13	0
1	800	common bean	wet season	18	47	n/a	0	13	0

2	7878	common bean	wet season	18	47	n/a	0	13	0
3	8112	common bean	wet season	8	47	n/a	0	13	0
4	2511	common bean	wet season	11	47	n/a	0	13	0
5	2759	common bean	wet season	8	47	n/a	0	13	0
6	900	common bean	wet season	13	47	n/a	0	13	0
7	900	common bean	wet season	9	47	n/a	0	13	0
8	240	common bean	wet season	7	47	n/a	0	13	0
9	1200	common bean	wet season	7	47	n/a	0	13	0
10	600	common bean	wet season	16	47	n/a	0	13	0
11	11160	common bean	wet season	6	47	n/a	0	13	0
12	900	common bean	wet season	25	47	n/a	0	13	0
13	900	common bean	wet season	28	47	n/a	0	13	0
14	900	common bean	wet season	16	47	n/a	0	13	0
15	900	common bean	wet season	13	47	n/a	0	13	0
16	900	common bean	wet season	14	47	n/a	0	13	0
17	3600	common bean	wet season	16	47	n/a	0	13	0
18	3000	common bean	wet season	7	47	n/a	0	13	0
19	30000	common bean	wet season	14	47	n/a	0	13	0
20	3600	common bean	wet season	165	n/a	2	0	11	18
1	800	Maize	dry season	370	n/a	4	0	11	41
2	7878	Maize	dry season	240	n/a	2	0	11	26
3	8112	Maize	dry season	263	n/a	3	0	11	29
4	2511	Maize	dry season	82	n/a	1	0	11	9

5	2759	Maize	dry season	153	n/a	2	0	11	17
6	900	Maize	dry season	265	n/a	3	0	11	29
7	900	Maize	dry season	90	n/a	1	0	11	10
8	240	Maize	dry season	84	n/a	1	0	11	9
9	1200	Maize	dry season	95	n/a	1	0	11	10
10	600	Maize	dry season	84	n/a	1	0	11	9
11	11160	Maize	dry season	131	n/a	1	0	11	14
12	900	Maize	dry season	315	n/a	3	0	11	35
13	900	Maize	dry season	256	n/a	3	0	11	28
14	900	Maize	dry season	168	n/a	2	0	11	18
15	900	Maize	dry season	110	n/a	1	0	11	12
16	900	Maize	dry season	185	n/a	2	0	11	20
17	3600	Maize	dry season	335	n/a	3	0	11	37
18	3000	Maize	dry season	93	n/a	1	0	11	10
19	30000	Maize	dry season	52	n/a	1	0	11	6
20	3600	Maize	dry season	219	n/a	2	0	10	22
1	800	Maize	wet season	290	n/a	3	0	10	29
2	7878	Maize	wet season	216	n/a	2	0	10	22
3	8112	Maize	wet season	143	n/a	1	0	10	14
4	2511	Maize	wet season	118	n/a	1	0	10	12
5	2759	Maize	wet season	220	n/a	2	0	10	22
6	900	Maize	wet season	199	n/a	2	0	10	20
7	900	Maize	wet season	126	n/a	1	0	10	13

8	240	Maize	wet season	80	n/a	1	0	10	8
9	1200	Maize	wet season	100	n/a	1	0	10	10
10	600	Maize	wet season	50	n/a	1	0	10	5
11	11160	Maize	wet season	73	n/a	1	0	10	7
12	900	Maize	wet season	385	n/a	4	0	10	39
13	900	Maize	wet season	200	n/a	2	0	10	20
14	900	Maize	wet season	188	n/a	2	0	10	19
15	900	Maize	wet season	50	n/a	1	0	10	5
16	900	Maize	wet season	187	n/a	2	0	10	19
17	3600	Maize	wet season	195	n/a	2	0	10	20
18	3000	Maize	wet season	123	n/a	1	0	10	12
19	30000	Maize	wet season	30	n/a	0	0	10	3
20	3600	Maize	wet season	50	13	n/a	4	10	40
1	800	Spinach	dry season	75	13	n/a	6	10	60
2	7878	Spinach	dry season	35	13	n/a	3	10	30
3	8112	Spinach	dry season	47	13	n/a	4	10	40
4	2511	Spinach	dry season	6	13	n/a	0	10	0
5	2759	Spinach	dry season	33	13	n/a	3	10	30
6	900	Spinach	dry season	39	13	n/a	3	10	30
7	900	Spinach	dry season	37	13	n/a	3	10	30
8	240	Spinach	dry season	32	13	n/a	2	10	20
9	1200	Spinach	dry season	32	13	n/a	2	10	20
10	600	Spinach	dry season	22	13	n/a	2	10	20

11	11160	Spinach	dry season	42	13	n/a	3	10	30
12	900	Spinach	dry season	77	13	n/a	6	10	60
13	900	Spinach	dry season	48	13	n/a	4	10	40
14	900	Spinach	dry season	63	13	n/a	5	10	50
15	900	Spinach	dry season	38	13	n/a	3	10	30
16	900	Spinach	dry season	53	13	n/a	4	10	40
17	3600	Spinach	dry season	63	13	n/a	5	10	50
18	3000	Spinach	dry season	28	13	n/a	2	10	20
19	30000	Spinach	dry season	38	13	n/a	3	10	30
20	3600	Spinach	dry season	45	13	n/a	3	7	21
1	800	Spinach	wet season	50	13	n/a	4	7	28
2	7878	Spinach	wet season	25	13	n/a	2	7	7
3	8112	Spinach	wet season	28	13	n/a	2	7	14
4	2511	Spinach	wet season	4	13	n/a	0	7	0
5	2759	Spinach	wet season	22	13	n/a	2	7	7
6	900	Spinach	wet season	56	13	n/a	4	7	28
7	900	Spinach	wet season	18	13	n/a	1	7	7
8	240	Spinach	wet season	22	13	n/a	2	7	14
9	1200	Spinach	wet season	35	13	n/a	3	7	21
10	600	Spinach	wet season	25	13	n/a	2	7	7
11	11160	Spinach	wet season	33	13	n/a	3	7	21
12	900	Spinach	wet season	73	13	n/a	6	7	42
13	900	Spinach	wet season	47	13	n/a	4	7	28

14	900	Spinach	wet season	37	13	n/a	3	7	21
15	900	Spinach	wet season	37	13	n/a	3	7	21
16	900	Spinach	wet season	42	13	n/a	3	7	21
17	3600	Spinach	wet season	37	13	n/a	3	7	21
18	3000	Spinach	wet season	27	13	n/a	2	7	14
19	30000	Spinach	wet season	33	13	n/a	3	7	21
20	3600	Spinach	wet season	208	13	n/a	0	7	0

[1]Level of damage=the sum of damaged individual crop parts per quadrat, in each farm

[2]Average number of leaves/seeds per bunch obtained from street vendors, local fresh produce markets

[3]Estimates of the number of individual corn cob (maize) damaged obtained by dividing the level of damage by 100 (this is to say 100 seeds damaged will make 1 average size corn cob)

[4]Number of damaged crop type = level of damage/average of number of leaves/seeds per bunch

[5]Average cost per bunch/individual crop type (street vendor prices) in South African Rand (R).

[6]Potential income loss (R)= number of damaged crop type *average cost.

Crop raiding by wildlife in subsistence homesteads in Northern KwaZulu-Natal, South Africa: farmers' perspectives

Abstract

Research on human-wildlife conflict between farmers and wildlife has focused on the concerns of commercial farmers. Yet, the experiences of the more vulnerable subsistence farmers are often neglected in such conflict. I investigated the experiences of subsistence farmers in response to crop raiding by wildlife alongside the Hluhluwe Game Reserve in KwaZulu-Natal Province, South Africa. I used a semi-structured questionnaire survey to obtain the perceptions and opinions of farmers about crop raiding by wildlife. These farms were situated close to and further away from the reserve boundary. I also assessed the relationship between the different types of control measures employed by farmers to deter crop raiding animals and factors influencing crop raiding (i.e. distance of farms from the reserve, crop raiding animals and crop types raided). The subsistence farmers reported insects to be the most important crop raiding taxon, and maize (*Zea mays*) was reported as the crop type most damaged during raids. Patrolling was the most commonly reported control measure used by farmers. The farmers differed in their opinions and perceptions of crop raiding behaviour in relation to their proximity to the reserve boundary. More farmers near the reserve reported experiencing crop raiding as compared to farmers further away from the reserve boundary. Moreover, farmers near the reserve reported a greater number of crop raiding species, crop types damaged, and were more inclined to use control measures, particularly patrolling, to deter crop-raiding animals compared to those farmers further away from the reserve boundary. I found that conflict between subsistence farmers and crop-raiding animals and attempts at mitigation are not homogenous and vary by distance from the Hluhluwe Game Reserve boundary.

Keywords: *control measures*, *crop raiding, human-wildlife conflict, rural community*

Introduction

The success of conserving biodiversity in protected areas, such as game reserves, depends on the opinions and perceptions of stakeholders to wildlife and conservation, especially of local human communities situated around these areas (Hill, 1997; Hill, 2000).

Crop raiding by wildlife is at the centre of shaping these opinions and perceptions because the frequency and intensity of such raiding will create either positive or negative opinions and perceptions about wildlife and conservation generally (Biquand & Biquad-Guyo, 1992; Lee *et al*., 1986; Naughton-Treves, 1997). The risk of attacks on people also significantly influences their attitudes towards crop raiding (Hill, 2000; Naughton-Treves *et al*., 1998). Such perceptions are notably focused on large species such as elephants (*Loxodonta africana*) and non-human primates, even when incidences of their raiding are rare (Gillingham & Lee, 1999; Sukumar, 1990). Importantly, past studies focused on commercial farmers with little attention on subsistence farmers (Biquand & Biquad-Guyo, 1992; Burton, 2002; Gautier & Biquand, 1994; Hill, 2000).

Expanding the scientific knowledge of farmers' perception and opinions of crop raiding behaviour is important because such behaviour tends to affect the livelihoods of people and can lead to retaliation by farmers (Newmark *et al*., 1993). For example, in Suikerbosrand Nature Reserve, South Africa, Pahad (2011) showed that some farmers responded to raiding chacma baboon (*Papio ursinus*) with lethal retaliation. Thus, local knowledge of the perceptions and opinions of crop raiding is needed to address issues about human-wildlife conflict (Adesina *et al*., 1994).

Perceptions and opinions of farmers about crop raiding often do not match the extent of damage caused by wildlife (Hill, 2000; Naughton-Treves, 1997; Siex & Struhsaker, 1999). Most studies reported that farmers tend to exaggerate the amount of loss (Hill, 2000; Naughton-Treves, 1997; Naughton-Treves *et al*., 1998). Hill *et al*. (2002) reported that people's perception and memory of past conflict could be influenced by different factors, and particular events may take on a greater significance in retrospect because farmers tend to overestimate their losses by as much as 30-35%. This might be because their experiences of crop raiding are layered on a series of beliefs that lead to potentially biased perceptions about certain wildlife species and their crop raiding behaviour (Chalise, 2000; Chalise & Johnson, 2001; Siex & Struhsaker, 1999).

Another important issue in human-wildlife conflict is the misidentification of problem species (Sillero-Zubiri & Switzer, 2001). For example, farmers around Kerinci Seblat National Park, Sumatra perceived the wild boar (*Sus scrofa*) to be a major crop pest, but this did not correspond with the observed spatial patterns of actual crop pests; raids by pig-tailed macaques (*Macaca nemestrina*) were more extensive than raids by wild boars, contrary to farmers' perceptions (Linkie *et al*., 2007). In Uganda, olive baboons (*Papio cynocephalus*) damaged crops and were considered by farmers as worse crop pests than red-tailed monkeys (*Cercopithecus ascanius*), which raided most frequently (Naughton-Treves, 1997). Similarly, in Zanzibar, negative attitudes toward red colobus monkeys (*Procolobus kirkii*) were linked to farmers wrongly blaming these monkeys of damaging bananas (*Musa paradisiaca*), which was actually caused by the smaller and less conspicuous Sykes monkeys (*Cercopithecus mitis*) that often intermingle with red colobus monkey troops (Siex & Struhsaker, 1999). Therefore, farmers' perceptions of damage, the raiding species and the measure of the extent of damage may not be reliable (Parry & Campbell, 1992; Pirta *et al.,* 1997).

One primary influence of farmers' perceptions of wildlife is the general cultural attitude of people towards wildlife (Biquand & Biquand-Guyot, 1992). In subsistence agricultural societies, the nuisance label of wildlife, due to crop damage and livestock depredation, is often pronounced (Hill, 1997, Hill *et al*., 2000; Hoare, 2000; Malik & Johnson, 1994; Ranjitsinh, 1984). Yet, some human communities consider wildlife as "brethren" (Biquand, 1994; Burton, 2002), which has enabled their survival throughout much of Asia (Southwick & Siddiqi, 1977, 1994). In Indonesia, around Lore Lindu National Park, tonkean macaque monkeys (*Macaca tonkeana*) are worshipped, protected and provisioned with food by villagers (Riley, 2007).

Most human wildlife conflict studies consider farm proximity to protected areas as an important predictor of crop raiding, with farms closer to protected areas being more vulnerable to raiding (Hill, 1997, 2000, 2002; Naughton-Treves, 1997, 1998; Sitati *et al*., 2005). For example, Hill (1997) considered the distribution of damage in Western Uganda and found that medium and large mammals damaged farms that were in close proximity to protected areas, whereas damage by rodents, birds and insects was ubiquitous. A study in Tanzania found that the most destruction by wildlife were in farms near the Serengeti National Park compared to farms that were in the middle and further away from the park (Mwakatobe *et al.*, 2014). Yet, studies have ignored the fact that opinions and perceptions of farmers might differ based on the location of the farms and the potential for conflict (Mwakatobe *et al*., 2014).

Control measures employed by farmers are important deterrents of crop-raiding animals (Thenkabail *et al*., 2010; Treves, 2008). Scarecrows and traditional crop guarding are considered to be important in deterring crop-raiding animals in subsistence communities (Hill, 2000). These communities are characterised by poverty and rely heavily on the crops they grow for subsistence, and most of them cannot afford effective control measures, such as exclusive fencing used on commercial farms (Naughton-Treves, 1997). In fact, very little has been written about subsistence farmers' knowledge of crop pests and their impact on standing crops or existing pests control measures (Hill, 2000). Yet this information is of importance in human-wildlife conflict studies (Naughton-Treves *et al*., 1998).

Generally, information of farmers' perceptions and opinions of crop raiding by wildlife are challenging to obtain and interpret because the information often varies from person to person, depending on their own experiences, their culture and religion and the influences of their friends and family, as well as neighbouring farmers (Kellert, 1993). Most studies on human-wildlife conflict are based on surveys examining perceptions of local farmers (Knight & Cowling, 1999; Lee & Priston, 2005). Surveys are the most efficient way to gauge the perceptions of people (Naughton-Treves, 1997; Siex & Struhsaker, 1999), despite the shortcomings and biases mentioned above. Furthermore, surveys can provide case-specific studies of wildlife conflict, which are lacking from many areas globally (Seoraj-Pillay & Pillay, 2016). Different regions have different conflict wildlife species and crop types, so perceptions might be context-specific (Chiyo *et al*., 2005; Sitati *et al*., 2005).

I investigated the perceptions and opinions of subsistence farmers on crop raiding by wildlife from the Hluhluwe Game Reserve in Northern KwaZulu-Natal Province, South Africa. Using a semi-structured questionnaire, I surveyed farmers who farmed close to and further away from the reserve boundary about their crop raiding experiences in order to assess 1) which wildlife species farmers perceived to be a problem and which types of crops were raided, and 2) the relationship between different types of control measures employed by farmers to deter crop-raiding animals and factors known to influence crop raiding (i.e. distance of farms from the reserve, crop raiding animals and crop types raided). I made three predictions. 1) Farmers' reports of crop raiding animals would be higher for vervet monkeys (*Chlorocebus pygerythrus*) compared to other crop raiding animals reported. Vervet monkeys are reported by most subsistence farmers adjacent to protected areas to be the most destructive animals as compared to most other wildlife in survey studies in Africa (Else, 1991; Hill, 2000; Naughton-Treves *et al*., 1998; Saj *et al*., 1999, 2001. Else (1991) included the vervet monkey amongst the three notorious primate pests in addition to rhesus monkey (*Macaca mulatta*) and yellow baboon (*Papio cynocephalus*) in Africa. 2) Maize (*Zea mays*) would be the most commonly reported crop type compared to all the other crops reported. Previous research has shown that most farmers report that maize is mostly targeted by crop raiding animals, and can be attacked at all stages of its development from the newly sown seed to cob maturity (Hill, 2000; Mwakatobe *et al*., 2014; Naughton-Treves, 1997). Maize was also reported as the most frequently grown food crop in most subsistence farming communities surveyed in Africa (Hill, 2000; Mwakatobe *et al*., 2014). 3) Crop raiding reports would be greater for farms near the reserve as compared to those further away from the reserve because farms close to the reserve are more accessible to wildlife.

Materials and methods

Study area

The study was conducted at Phindisweni village (28^{o}26' S; 31^{o} 09''E), a subsistence farming community on the edge of the Hluhluwe Game Reserve (28^{o}00' S; 31^{o} 43''E; Figure 4.1). Homesteads within the study area comprised the study population.

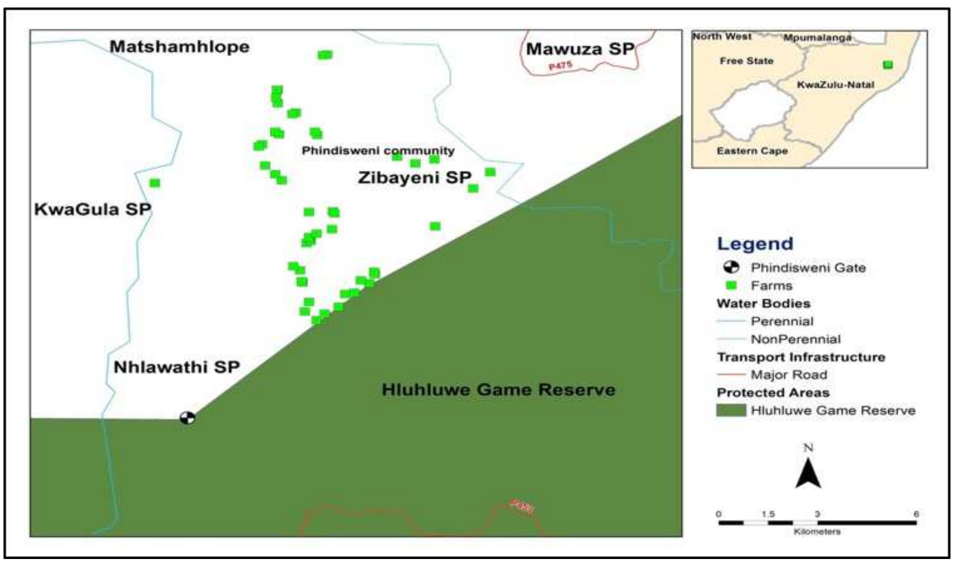

Figure 4.1. Location of the study site, Phindisweni village, in relation to the Hluhluwe Game Reserve, KwaZulu-Natal Province, South Africa, with the surveyed farms (green squares) Inset: position of study site in KwaZulu-Natal Province (green square) in South Africa.

The village was characterised by homesteads with high levels of poverty (StatsSA, 2011). Approximately 96% of the community members depended on crop-based agriculture for their subsistence (StatsSA, 2011). The need for reticulated water, sanitation and electricity were the most pressing issues in the community, with only one homestead reported to have electricity in the 2011 census. These farms were located on mainly hilly terrain. The natural vegetation type in this community was savannah grassland (Cromsigt *et al*., 2017). Like most farming communities abutting protected areas in Africa, this community was affected by crop raiding by wildlife historically (Infield, 1986, 1988) as well as during my study.

Data collection and sampling procedure

I administered 60 semi-structured questionnaires to 60 different farmers. The questionnaires were administered with the help of two local research assistants in March 2016. I trained the research assistants about the survey protocol and they were also given colour photographs of wildlife in the Hluhluwe Game Reserve with names in English and isiZulu (the local language) to assist respondents in identifying crop raiding species. Interviews were conducted in IsiZulu. Permission to carry out this research was granted by the Human Ethics Research Committee (HREC) (non-medical), University of the Witwatersrand, under protocol number H15/11/29. The chief of the Phindisweni community was approached for permission to survey the community. The purpose of the survey was explained to the chief and the potential interviewees.

I used a stratified sampling approach to sample the homesteads. I selected every second homestead for the interview. The selection of the homesteads was done in such a way that the homesteads were located a maximum of 6 km from the reserve boundary. I used Garmin Map62 GPS handheld device to collect straight-line farm distances of each farm from the reserve boundary. A frequency distribution of distances of farms from the reserve boundary generated a bimodal distribution between farms less than 3km and those greater than 3km. I therefore designated farms 1-3km of the reserve boundary as near and farms 4-6km as further from the reserve.

The potential interviewees were asked whether they wanted to participate in the survey and only if they agreed did the interview proceed. I restricted the survey to one respondent per homestead to avoid pseudo-replication of results. The identity of all respondents remained anonymous during this study as outlined in the conditions of my ethics permit. I gathered signed consent forms (e.g. Appendix I) from each respondent to participate in the study before conducting each survey.

The aims of the project were briefly explained to the potential interviewee. Interviews took 30 to 40 minutes per respondent to complete. The questions were both closed and open-ended and were aimed at extracting the respondents' answers on crop raiding. All respondents interviewed were adults over 18 years of age and each was informed that sensitive information and personal characteristics would not be included in any reports without their permission. An average of 7 interviews took place per day.

Questionnaires structure and content

The semi-structured questionnaire used was adopted from Seoraj-Pillai (2016) and modified for my study (Appendix III). The questionnaire provided clear instructions on answering each question by giving predefined answers or categories and options. The questionnaire was divided into five sections, i.e. demographic information, farm attributes, crop damage, mitigative strategies, and opinions and perceptions of farmers on crop raiding. The nature of the farming practice (i.e. the degree of subsistence practice) were assessed by asking questions about homestead income, occupation and type of crops planted to determine the degree to which these farmers were dependent on agriculture alone for their livelihood. I also asked farmers questions associated with crop raiding, such as experience with crop raiding, crop storage and crop raiding pre-and post-harvest, the time of day crop raiding was experienced, evidence used to identify raiders, the size of farms damaged in one growing season and how crops contributed to the homestead basket.

For the opinions and perceptions, I specifically asked farmers questions directly related to crop raiding, including which wildlife species were responsible for crop raiding (respondents were allowed to choose 'other' when they were unsure of the animal responsible for crop raiding), type of crops damaged and the control measures they employed to deter crop raiders.

Questionnaire data capturing and coding

I captured the data in Microsoft Excel. Predetermined numerical codes were assigned to responses to code them for processing and analysis. Data for each question was captured in a separate worksheet of the Excel file. For example, responses for question number 1 for sex were entered in the same worksheet for all the questionnaires sampled and assigned numerical codes 1 for male and 2 for female. A separate worksheet was created with the questions and column headings indicating the actual response and the respondent's farm number. The respondent's farm number was labelled according to their distance from the reserve boundary. Questions that were not answered in the survey were considered non-responses.

Multivariate responses were split into separate cells into consecutive rows; for example, if a respondent indicated that the evidence they used to identify crop raiding animals was bites, droppings and tracks, each evidence appeared on a separate row, and the participant farm number and distance from the reserve was repeated for each respondent. Most of the questions allowed for dichotomous answers, coded as yes and no. There were few trichotomous questions that required yes, no, no response/not sure and/or do not know.

Data analysis

I provided descriptive summaries concerning demographic information of farmers, the extent and impact of crop raiding and subsistence and farming patterns. Otherwise, I used generalised linear mixed models (GLMM, Baayen, 2008) with one category set as a reference, to which others were compared to analyse the data. A GLMM was appropriate as it allowed for the specification of models with non-normally distributed residuals. I applied three separate GLMMs fitted via maximum likelihood in R (version 3.3.3, 2017) with a *glmer* function and a binomial distribution (lme4 package, Bates *et al*. 2015) to ascertain the farmers' perceptions and opinions on crop raiding. The number of 'yes' and 'no' responses (response variable) were analysed separately for farmers affected by crop raiding, crop raiding animal type and crop types reported (dependent variables). The models compared the fixed effects parameter of farm location from the reserve (near and far). Farm number was set as a random factor (intercepts only) to account for farm location.

I investigated the relationship between control measures (dependent variable) employed by farmers and their reports of three independent variables: crop raiding animal type, crop types raided and the distance of farms from the reserve boundary. These issues were considered separately during the survey, so I applied a multinomial logistic regression analysis fitted from the nnet package in R (version 3.3.3, 2017) with a multinom function to assess the relationship between the variables mentioned above.

All models were two-tailed and alpha was set at 0.05. I report coefficient estimates, including the residual degrees of freedom, standard errors, Z-values, corresponding P-values and confidence intervals (CI). CIs were used to assess significant contributors of components of predictors. All graphs were produced using the ggplot2 package from the R statistical software.

Results

Of the 60 questionnaires administered, two questionnaires were incomplete and were not used in the analysis. Therefore, the sample size for this study was 58.

Demographic information of farmers

I interviewed homestead heads or resident adults (≥ 18 years old) of whom 62% of the respondents were male and 38% were female. All respondents interviewed listed isiZulu as their first language. Most (n = 43; 74%) respondents reported to have primary school education, and 14 respondents (24%) had high school education. One participant had tertiary education. Most respondents (n = 43; 74%) occupied large homesteads of more than six people.

The extent and impact of crop raiding

A total of 31 (53%) respondents out of 58 experienced crop raiding while 27 (47%) did not experience crop raiding in the most recent season preceding my survey. Only one respondent did not experience crop raiding at all during the previous season but had done so at other times. Of the 31 respondents that experienced crop raiding in the most recent season, 27 (47%) of the respondents claimed that they experienced raids 1 to 4 times per month and four (7%) reported experiencing crop raiding > 4 times a month. All respondents reported storing crops after harvest, but only one participant had stored crops during the study. Raids were reported by 55 respondents (94%) to take place at night, while three respondents (5%) reported raids taking place in the morning. None of the respondents reported raids during the day or in the afternoon.

Animal scats were reported by 43 respondents (74%) as evidence for identifying crop-raiding animals, while 15 (26%) reported tracks and four (7%) reported signs of bites on crops. When asked what was the cause of crop raiding, 42 (72%) respondents mentioned the proximity of farms to the reserve, while nine (16%) reported poor guarding methods, four (7%) reported lack of grazing land and three (5%) chose not to respond to this question. Seventeen respondents reported less than half of their farms being damaged at a given time, while 31 respondents reported about 1m^2 of their farms being damaged. Ten farmers chose not to respond to this question.

Of the 58 participants, 69% reported that crops contributed 91-100% to their homestead food basket, with 57 respondents reporting that wildlife damaged their farm pre- and post-harvest. Almost all (55) respondents reported disposing of crop parts that were damaged, and all respondents reported that crop raiding affected livelihoods in their community and 40 respondents reported food shortage as a problem in their community.

Subsistence farming patterns

Most respondents (n = 42, 72%) practised subsistence farming, while the remaining 16 (28%) selected commercial as their farming practice, and none of the respondents farmed for leisure. However, it should be noted that the 16 farmers claiming to practice commercial farming planted subsistence crops such as spinach (*Spinacia oleracea*) and cabbage (*Brassica oleracea var.*) to sell to their local community and not as a larger commercial enterprise (e.g. a market stall). Sources of income included working for the Hluhluwe Game Reserve (n = 15; 25%), craft making (n = 10; 17%), hunting (n = 3, 5%) and other (n = 11; 18%). In total, 19 respondents (32%) claimed to be unemployed and 17 (29%) of the respondents claimed to fall under the smaller income group (< R500/month).

Crop raiding experiences by distance from the reserve

Crop raiding experiences (Wald χ^2_1 = 9.74, P < 0.001), distance of farms from the reserve (Wald χ^2_1 = 1.44, P < 0.001) and the interaction between crop raiding experiences and distance of farms from the reserve (Wald χ^2_1 = 0.87, P = 0.001) were significant predictors of crop raiding reports. Significantly higher numbers of farmers experienced crop raiding as compared to farmers who did not experience crop raiding (CI = 0.825; 0.830), with higher number of farmers near the reserve boundary experiencing crop raiding than those further away from the reserve boundary (CI = -0.264; -0.034; Figure 4.2).

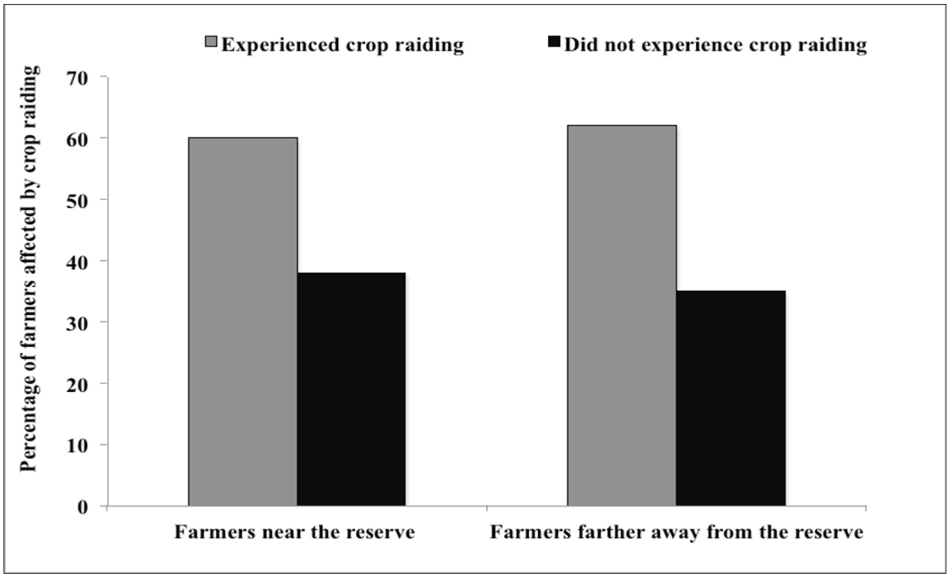

Figure 4.2. Percentage of responses by farmers about crop raiding experiences near and further away from the Hluhluwe Game Reserve, South Africa. Asterisks above bars represent two levels of interpretation, i.e. differences in responses between farmers near and further away from the reserve boundary and farmers who experienced crop raiding and those that did not experience crop raiding.

Crop-raiding animals

Respondents reported the following crop raiding species: cane rat (*Thryonomys swinderianus*); duiker (*Cephalophus* spp.); elephant (*Loxodonta africana*), hare (unknown species); house rat (*Rattus rattus*); porcupine (*Hystrix africaeaustralis*), vervet monkey (*Chlorocebus pygerythrus*); warthog (*Phacochoerus africanus*); wild pig (*Sus scrofa*), other mammals; free-living birds (unknown spp.); and insects. Domestic goats (*Capra aegagrus hircus*) were also mentioned as crop raiders (Figure 4.3).

Reports of crop raiding were significantly affected by crop raiding animal type (Wald χ^2_{12} = 87.76, P < 0.001) and the interaction between animal type and farm distance from the reserve (Wald χ^2_{12} = 23.13, P = 0.026), but there was no significant effect for the farm distance to the reserve boundary (Wald χ^2_{1} = 0.36, P = 0.544). Significantly higher numbers of farmers reported crop raiding by insects as compared to all other crop raiding animals and significant differences were found between farmers' responses for cane rat, duiker, elephant, hare, house rat, porcupine, warthog, wild pig, other mammals, insects and goat whereas no significant differences were found between farmers' responses for vervet monkey and free-living birds (Figure 4.3; Table 4.1).

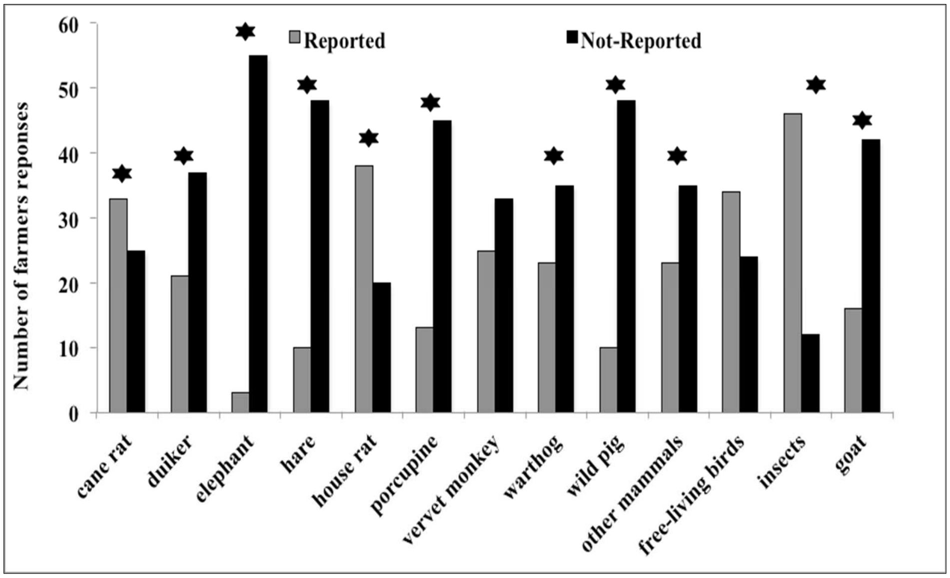

Figure 4.3. The number of farmers that did and did not report different crop raiding animals at the edge of the Hluhluwe Game Reserve boundary, South Africa. Asterisks above bars show significant differences between farmers that reported a particular crop raiding animal type vs those that did not report that animal type.

Table 4.1. Output of a GLMM model showing farmers' reports about crop raiding animal types on the edge of the Hluhluwe Game Reserve, South Africa. Significant values are shown in bold.

Crop raiding animal	Std error	Z value	P value	CI 2.5%	CI 97.5%
Cane rat	**0.032**	**0.36**	**P<0.001**	**0.113**	**0.6372**
Duiker	**0.085**	**-0.20**	**P=0.001**	**-0.696**	**-0.120**
Elephant	**0.451**	**-4.48**	**P=0.039**	**-4.054**	**-0.104**
Hare	**0.143**	**-5.41**	**P=0.005**	**-1.678**	**-0.283**
House rat	**0.121**	**5.88**	**P<0.001**	**0.650**	**1.182**
Porcupine	**0.143**	**-4.98**	**P=0.046**	**-0.932**	**-0.007**
Vervet monkey	0.085	4.25	P=0.086	0.276	-0.980

Warthog	**0.066**	**9.36**	**P<0.001**	**0.350**	**0.906**
Wild pig	**0.137**	**-4.84**	**P=0.005**	**-1.678**	**-0.283**
Other mammals	**0.087**	**-0.79**	**P<0.001**	**-0.090**	**-0.536**
Free-living birds	0.072	4.31	P=0.163	0.285	-0.833
Insects	**0.060**	**25.39**	**P<0.001**	**1.716**	**2.211**
Goat	**0.104**	**-3.47**	**P=0.016**	**-0.090**	**-0.536**

Significantly higher number of farmers near the reserves reported that cane rat, duiker, hare, porcupine, vervet monkey, warthog, wild pig, other mammals and free-living birds raided crops than those further away from the reserve. No significant differences were found between farmers' responses for house rat and insects near and further from the reserve, but the highest number of farmers across all farm distances reported crop raiding by insects (Figure 4.4). In contrast, raiding by elephants and goats were reported by significantly higher number of farmers further away from the reserve as compared to those closer to the reserve (Figure 4.4; Table 4.2).

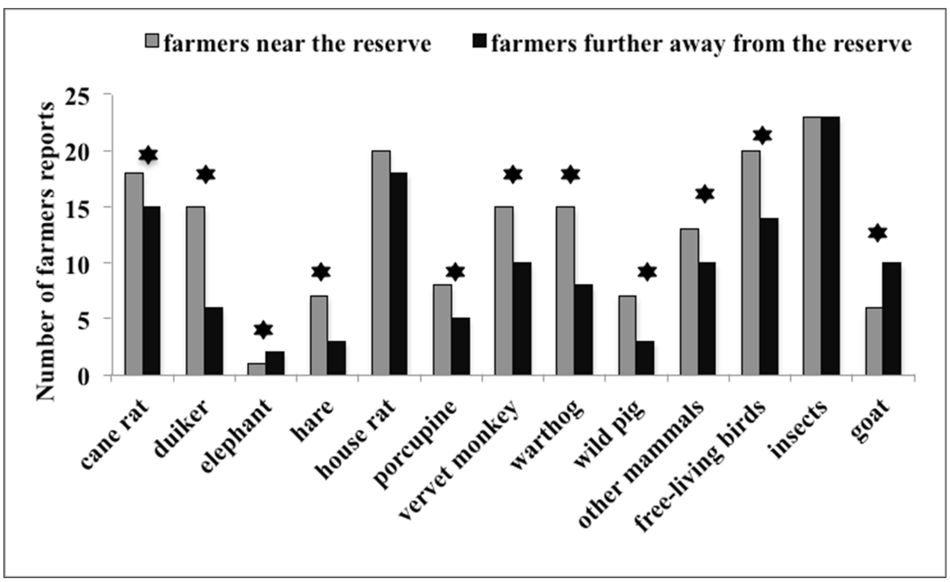

Figure 4.4. The number of farmers that reported crop raiding animals on farms near and further away from the Hluhluwe Game Reserve boundary, South Africa. Asterisks above bars show significant differences between farmers located near and further away from the reserve for the particular crop raiding animal type.

Table 4.2. Output of a GLMM model showing the crop raiding animal types reported by farmers near and further away from the Hluhluwe Game Reserve, South Africa. Significant values are shown in bold.

Crop raiding animal	**Std error**	**Z value**	**P value**	**CI 2.5%**	**CI 97.5%**
Cane rat	**0.060**	**0.76**	**P=0.000**	**-0.036**	**-0.322**
Duiker	**0.745**	**-4.23**	**P<0.001**	**-4.618**	**-1.697**
Elephant	**1.179**	**-4.85**	**P<0.001**	**-8.039**	**-3.417**
Hare	**0.819**	**-5.06**	**P<0.001**	**-5.750**	**-2.539**
House rat	0.728	-1.58	P= 0.113	-5.750	2.539
Porcupine	**0.792**	**-4.90**	**P<0.001**	**-5.437**	**-2.330**
Vervet monkey	**0.725**	**-3.50**	**P<0.001**	**-3.965**	**-1.121**
Warthog	**0.719**	**-2.43**	**P= 0.013**	**-3.179**	**-0.360**
Wild pig	**0.865**	**-5.19**	**P<0.001**	**-6.194**	**-2.800**
Other mammals	**0.730**	**-3.78**	**P<0.001**	**-1.446**	**-1.677**
Free-living birds	**0.719**	**-2.43**	**P= 0.014**	**-3.163**	**-0.344**
Insects	0.796	0.14	P= 0.884	-2.578	0.276
Goat	**0.729**	**-3.72**	**P< 0.001**	**-4.145**	**-1.285**

Types of crops raided

Farmers near and further away from the reserve reported banana (*Musa paradisiaca*), beetroot (*Beta vulgaris*), butternut (*Cucurbita moschata*), cabbage *(Brassica oleracea var. capitata),* common bean (*Phaseolus vulgaris*), guava (*Psidium guajava*), maize (*Zea mays*), mango (*Mangifera indica*), orange (*Citrus aurantium*), peach (*Prunus persica*), potato (*Solanum tuberosum*), pumpkin (*Cucurbita pepo*), spinach (*Spinacia oleraceae*), sweet potato (*Ipomoea batatas*), and yam (*Colocasia esculenta*), as crops raided in their farms (Figure 4.5).

Crop raiding reports were significantly affected by crop type (Wald χ^2_{14} = 105.92, P < 0.001) and the interaction between crop type and distance of farms from the reserve (Wald χ^2_{14} = 29.26, P = 0.009), but distance of farms from the reserve was not a significant predictor of crop raiding reports (Wald χ^2_{1} = 2.11, P = 0.145). Significantly higher number of farmers reported that maize (*Zea mays*) was mostly damaged compared to all the other crop types and significant differences were found between farmers' responses for banana, beetroot, butternut, cabbage, guava, maize, peach, potato, pumpkin, spinach and yam whereas no significant differences were found between farmers responses for common bean, mango, orange and sweet potato (Figure 4.5; Table 4.3).

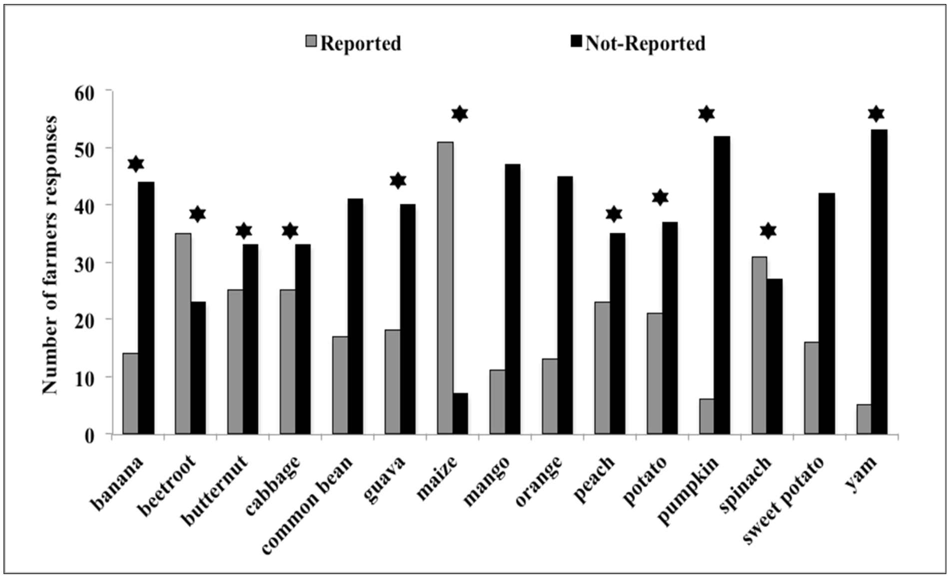

Figure 4.5. The number of farmers that did and did not report raiding of different crop types at the edge of the Hluhluwe Game Reserve boundary, South Africa. Asterisks above bars show significant difference between farmers that reported a particular crop type was raided vs those that did not report that crop type.

Table 4.3. Output of a GLMM model showing farmers' reports for crop types raided on the edge of the Hluhluwe Game Reserve, South Africa. Significant values are shown in bold.

Crop type	**Std error**	**Z value**	**P value**	**CI 2.5%**	**CI 97.5%**
Banana	**7.114**	**-3.50**	**P=0.000**	**-10.452**	**-4.285**
Beetroot	**15.035**	**2.03**	**P= 0.041**	**1.140**	**60.074**
Butternut	**5.905**	**2.45**	**P=0.014**	**2.908**	**26.056**
Cabbage	**5.916**	**2.45**	**P=0.014**	**2.921**	**26.114**
Common bean	2.493	1.67	P= 0.941	-0.713	9.058
Guava	**2.760**	**1.96**	**P=0.049**	**0.007**	**10.825**
Maize	**14.918**	**2.82**	**P=0.004**	**12.834**	**71.311**

Mango	4.168	-1.38	P=0166	-13.936	2.402
Orange	2.030	-0.95	P=0.337	-5.924	2.032
Peach	**4.938**	**2.38**	**P=0.172**	**2.084**	**21.439**
Potato	**4.346**	**2.18**	**P=0.029**	**0.964**	**17.999**
Pumpkin	**5.466**	**-2.56**	**P=0.010**	**-24.737**	**-3.312**
Spinach	**12.158**	**2.16**	**P=0.030**	**2.476**	**50.136**
Sweet potato	2.232	1.24	P=0.213	-1.597	7.149
Yam	**7.613**	**-2.25**	**P=0.024**	**-32.066**	**-2.222**

Moreover, significantly higher number of farmers near the reserve reported greater raiding of beetroot, maize and spinach than farmers further away from the reserve; no other crop types were significantly affected by distance from the reserve (Figure 4.6; Table 4.4).

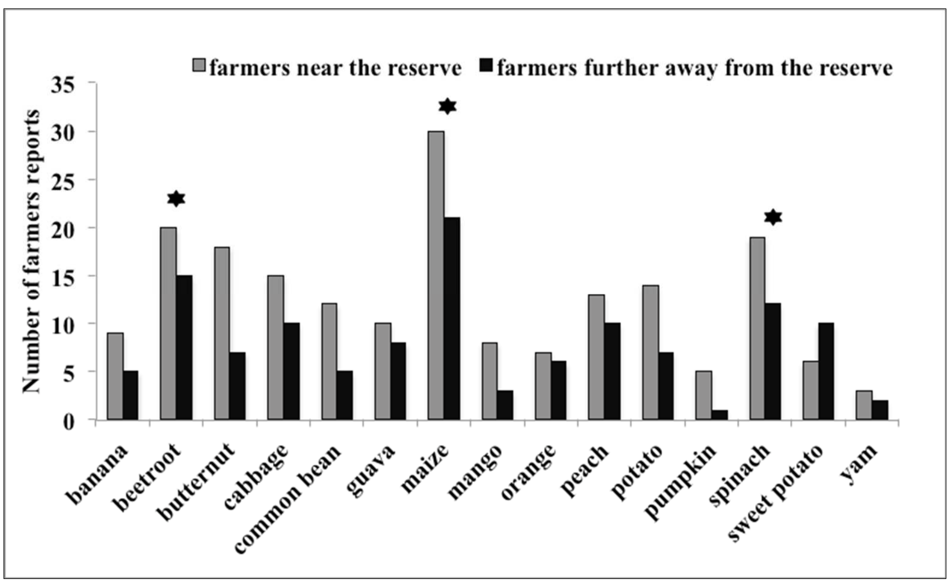

Figure 4.6. The number of farmers that reported crop types raided on farms near and further away from the Hluhluwe Game Reserve boundaries, South Africa. Asterisks above bars show significant difference between farmers' reports near and further away from the reserve for the particular crop type reported.

Table 4.4. Output of a GLMM model showing crop types damaged as reported by farmers near and further away from the Hluhluwe Game Reserve, South Africa. Significant values are shown in bold.

Crop type	**Std error**	**Z value**	**P value**	**CI 2.5%**	**CI 97.5%**
Banana	0.324	7.58	P=0.104	-1.026	3.003
Beetroot	**0.667**	**3.00**	**P= 0.002**	**0.697**	**3.313**
Butternut	0.695	0.68	P=0.495	-0.889	1.836
Cabbage	0.669	1.61	P=0.106	-0.231	2.393
Common bean	0.736	-0.02	P= 0.979	-1.462	1.424
Guava	0.683	1.01	P=0.311	-0.648	2.031
Maize	**0.755**	**4.90**	**P<0.001**	**2.228**	**5.189**
Mango	0.830	-0.81	P=0.415	-2.304	0.951
Orange	0.711	0.35	P=0.725	-1.144	1.644
Peach	0.669	1.63	P=0.103	-0.220	2.403
Potato	0.695	0.68	P=0.495	-0.888	1.837
Pumpkin	1.200	1.34	P=0.113	-4.253	0.450
Spinach	**0.663**	**2.20**	**P=0.027**	**0.161**	**2.764**
Sweet potato	0.669	1.63	P=0.102	-0.218	2.405
Yam	0.934	-1.22	P=0.222	-2.974	0.690

Control measures

All respondents reported using several different types of control measures (i.e. patrolling, fencing, pesticides and trapping) to deter crop-raiding animals on their farms. I used a multinomial logistic regression to assess the combined relationship of control measures vs crop raiding animals, crop types raided and distance from the reserve boundary. The analysis revealed that crop raiding animal types (Wald $\chi^2_4 = 33.58$, $P < 0.001$), crop types raided (Wald $\chi^2_4 = 96.28$, $P < 0.001$) and distance of farms from the reserve boundary (Wald $\chi^2_4 = 11.70$, $P = 0.019$) all had a significant effect on the choice of control measures farmers used. Overall, more farmers chose patrolling compared to fencing, pesticides and trapping, but pesticides were chosen more than patrolling, fencing and trapping for crop raiding animals (Figure 4.7).

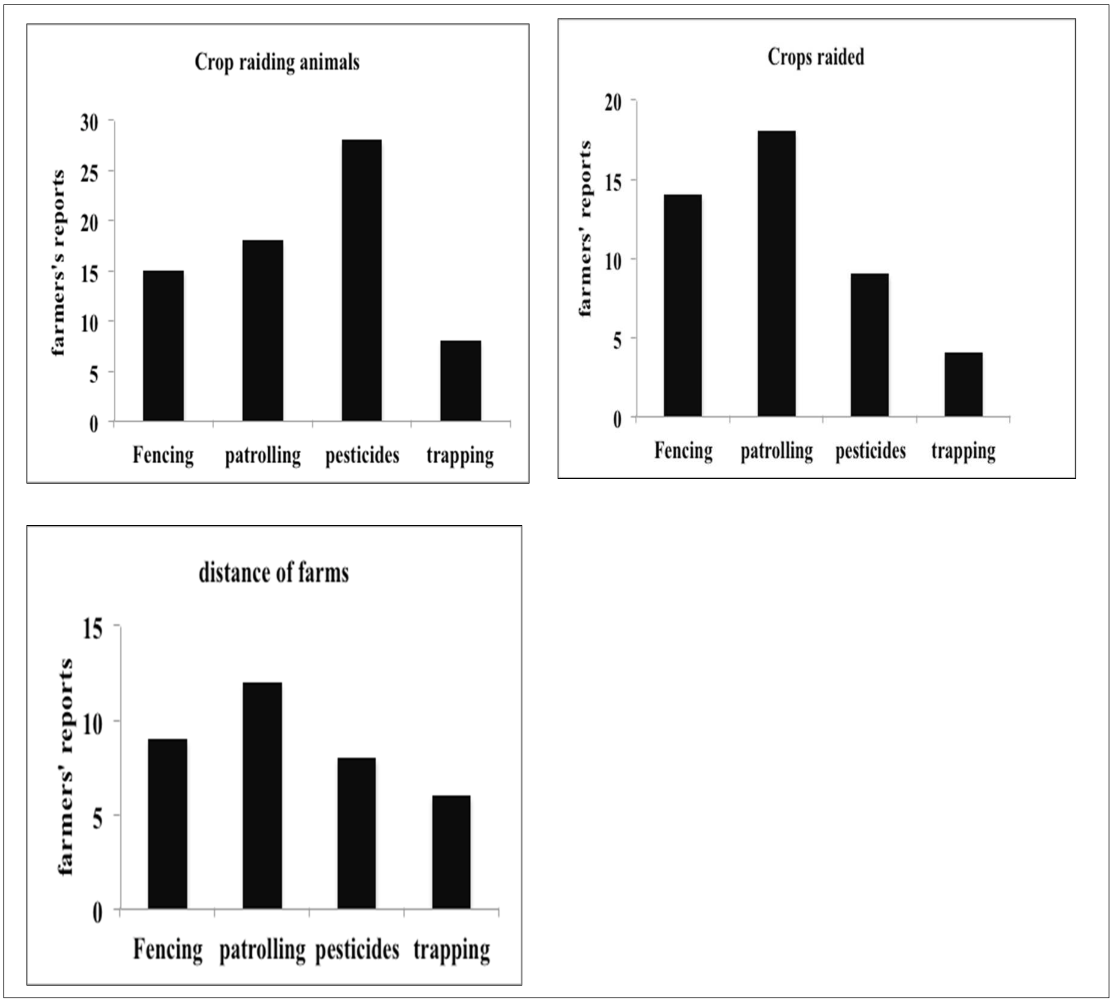

Figure 4.7. The number of reports about the control measures (fencing, patrolling, pesticides and trapping) used by farmers to deter crop raiding animals (top left), prevent crop damage (top right), and the distance (bottom left) from the edge of Hluhluwe Game Reserve, South Africa.

Discussion

I investigated the perceptions and opinions to crop raiding by subsistence farmers on the edge of the Hluhluwe Game Reserve. Insects were reportedly the most important crop-raiding animals, which was contrary to my prediction that mammals would be the major pests. Many studies in Africa reported insects as one of the major problems in agricultural land (Gillingham & Lee, 1999; Hill, 2000; Naughton-Treves, 1997; Treves *et al*., 2006) and the damage they cause is always reported as widespread (Hill, 1997; Naughton-Treves *et al*., 1998). In Uganda, Hill (1997) found that insects caused widespread damage to crops. In contrast, near the Selous Game Reserve in Tanzania, Gillingham & Lee (1999) found a surprisingly lower number of insects crop raiding reports from farmers.

I expected vervet monkeys to be the most reported crop raider. Vervet monkeys are often singled out as the most problematic animals in most human-wildlife conflict studies worldwide (Gillingham & Lee, 1999; Hill, 2000; Naughton-Treves, 1997; Treves *et al*., 2006). In Entebbe, Uganda, Saj *et al.* (2003) found that vervet monkeys were responsible for the most crop damage in gardens surveyed. The results from a concurrent study on assessing wildlife raiders showed that primates did not transgress the Hluhluwe Game Reserve boundary onto neighbouring farmers (Chapter 2), which might explain the low reports of this species by the farmers. In addition, damage by elephant reports was negligible. It is not surprising that elephant raids were low unlike the rest of Africa; South African reserves (including HGR) are fenced, which dramatically reduces elephant-human conflict (Kaswamila, 2007; Mwakatobe *et al*., 2014; Ntalwila *et al*., 2003). Elephants have been reported to be the most destructive wildlife in Tanzania and Uganda (Kaswamila, 2007; Mwakatobe *et al*. 2014; Ntalwila *et al*., 2003).

Farmers reported a range of food crops being targeted by crop raiding animals. As expected and consistent with other human-wildlife conflict studies (Hill, 1997; Mackenzie, & Ahabyona, 2012; Mwakatobe *et al*., 2014), farmers reported that maize (*Zea mays*) was the most damaged. Mackenzie & Ahabyona, (2012) found that in the 25 villages around Kibale National Park, Uganda, wild animals raided maize out of 24 different available crops. Pienkowski *et al.* (1998) found that maize raiding was unaffected by the availability of forest fruit abundance, and maize experienced the highest damage compared to all the other food crops near Kibale National Forest in Uganda. Maize is the food crop favoured above other crops by people and crop-raiding herbivores and omnivores (King & Lee, 1987).

In many African societies, maize is a preferred food crop because it provides a higher yield for lower input of labour (Shiferaw *et al*, 2011). Thus, maize is a staple and food security crop in South Africa (Altman *et al*., 2009). Yet, the nutritional value of maize makes it more vulnerable to raiders such as primates as compared to most crops raided (Shiferaw *et al*, 2011). In addition, because it is such an important crop in most subsistence homesteads in Africa and it is usually the most abundant crop grown (Koki *et al*., 2010; Naughton-Treves, 1997; Ntalwila *et al*., 2003; Walpole *et al*., 2004). Thus, maize could be attacked more often by chance. Alternatively, people are particularly aware of any damage their maize crops suffer because of its value (Hill, 1997; Siex *et al*., 1999). Hill (1997) and Shiferaw *et al* (2011) reported that the crops people consider to be vital to their subsistence are also the crops they perceive to be most vulnerable to damage from wild animals. While maize has been identified as a frequently raided crop (Atteh, 1984; King & Lee, 1987; Marples, 1976), Shiferaw *et al*. (2011) reported that the standing crop of maize is more resistant to bird damage and stored maize crops are more resistant to insect infestation. Interestingly, insects and birds were reportedly prominent crop raiders in my study.

Consistent with my prediction, significantly more crop raiding incidences were reported by farmers near the reserve compared to farmers further away. This finding is consistent with many studies that crop raiding is greatest in close proximity to the protected areas (Hill, 1998; Hoare, 2000). Hill (1997) mentioned that distance of field boundaries from a forest or other protected areas heightens the likelihood of incursion by wildlife into surrounding farms. Naughton-Treves *et al*. (1998) reported that in villages around Kibale National Park, Uganda, crop damage was correlated with the distance of the property from the forest edge, suggesting that the greater the distance between a garden and a forested boundary, the greater the property was buffered (Naughton-Treves *et al*., 1998).

I investigated the relationship of farmers' choice of control measures and factors known to influence crop raiding (i.e. crop raiding animals, crops raided and farms distance from the reserve). Farmers resorted to physical barriers (i.e. fencing), patrolling, trapping and the use of pesticides to protect their crops from raiders. Karidozo & Osborn (2007) also found that a combination of crop protection methods would better protect crops from wild animals. However, Fungo (2011) mentioned that the selection of available methods for farm protection depends on the species of animal that must be dealt with. For example, most commercial farmers use exclusive fencing, but most rural subsistence farmers cannot afford such fencing.

Specifically, most farmers used pesticides against crop raiding animals (insects mainly) as compared to the other control measures for crop raiding animals. In addition, many farmers used patrolling to prevent crop damage. Farmers, both near and further away, from the reserve used patrolling more than other control measure (fencing, pesticides and trapping) respectively. Patrolling was the most prominent control measure associated with crop raided and distance of farms from the reserve (Figure 4.7), typical for subsistence farming communities near protected areas in Africa (Fungo, 2011; Mwakatobe *et al*., 2014). For example, in Tanzania, patrolling (86% of farms) was used more than fencing (14% of farms) at all farm distances from the Serengeti National Park boundary in Tanzania (Mwakatobe *et al.*, 2014). While patrolling is the most effective short-term control measure, it is ineffective on raiders such as insects. Thus, farmers in my study also used pesticides against insects, consistent with other studies (Strong *et al*., 1984).

Patrolling and crop guarding are considered to be important in deterring crop-raiding animals in subsistence farming communities (Hill, 2000; Infield, 1988). These communities are characterised by poverty and rely heavily on the crops they grow for subsistence. Most farmers cannot afford effective control measures, such as exclusive fencing to deter crop-raiding animals as seen in commercial farming (Naughton-Treves, 1997). However, time spent patrolling and guarding pose several opportunity costs for individuals engaged in such activities (Treves, 2009; Walker, 2012). In parts of Asia and Africa, the onus of patrolling the fields at night falls on men, whilst during the day it is frequently the responsibility of children to patrol the farms (Hoare, 2000). For children, patrolling has been shown to lead to poor school performance (Mackenzie & Ahabyona, 2012). Consequently, future employment may be jeopardised (Hill, 2000). Patrolling fields is also known to cause fatigue and teenagers may drop out of school for patrolling sessions during the crop growing seasons (Barua *et al*., 2013; Infield, 1988).

In conclusion, successful conservation of wildlife in protected areas adjacent to agricultural areas requires knowledge of crop raiding by wildlife. The first step in acquiring this knowledge is to develop a plan that involves farmers and consider their perceptions and opinions, particularly about factors that can exacerbate crop raiding. Consistent with my predictions on crop raiding experiences, farmers reported maize (*Zea mays*) as the most raided crop type, and raiding differed by their distance from the reserve boundary. In contrast to my prediction, insects were reportedly the most crop raiding animals rather than vervet monkeys. The opinions and perceptions of the subsistence farmers in my study were generally similar to views expressed by farmers in other parts of Africa, highlighting the common experiences in marginalised communities (Seoraj-Pillai & Pillay 2016). I am mindful that the opinions and perceptions of farmers in my study might have been shaped by factors other than personal experiences of crop raiding. For example, hearsay from neighbouring farmers is known to shape opinions, often as a means to gain compensation for crop loss (Kyamnywa *et al*., 2011; Naughton-Treves, 1997; Sillero-Zubiri *et al*., 2007; Treves *et al*., 2006). Nonetheless, my study is perhaps one of the first studies to have systematically investigated the views of subsistence farmers about human-wildlife conflict.

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Appendix I: Consent form

UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCE

Date: ________________________
Questionnaire number______________________ Farm/storage number___________

I, __________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, and anticipated inconvenience of participation.
I have read (or had explained to me) and understood the study as explained in the information sheet. I have had sufficient opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty.
I am aware that the findings of this study will be processed into a research report, journal publications and conference proceedings, and there are no benefits in participating in this study, but that my participation will be kept confidential unless otherwise specified or permission is sought from me.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname: ____

Participant Signature: _____________________Date: _______________________

Researcher's Name & Surname: ____

Researcher's Signature: ___________________Date: _______________________

Appendix II: Information sheet-farmers survey

UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCE
THE IMPACT OF CROP RAIDING ON SUBSISTENCE FARMERS
QUESTIONNAIRE SURVEY

I am conducting a research study to find out the impact of crop raiding behaviour by wildlife on your farms, and I will like you to participate in a questionnaire survey for my PhD study. My research study sought to investigate the potential damage that small mammals and non-human primates crop raiding behaviour can cause to farms of subsistence homestead. I want to find out how this damage can exacerbate food insecurity in your community.

You are chosen from the list of subsistence farmers from your tribal offices (Esibayeni) as an active subsistence farmer. You are chosen to participate in this study because you are planting crops all year round. Should you agree to participate in my study, I will be asking you demographic information and farming history related questions; all will be in a questionnaire format, which will be read out to you in your home.

Participating in this study is voluntary, and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason. This study is solemnly intended for a PhD thesis. Therefore, there will be no payment or reward for participation. Any participant throughout their participation in the study will incur no cost in monetary value or otherwise.

Feedback on the findings of this project will be made available through Hluhluwe Imfolozi Park research centre. All information gathered in this survey will be kept confidential until it is analysed. Your answers will be given a code number or a pseudonym, and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings. Otherwise, records that identify you will be available only to people working on the study. The researcher will store hard copies of your answers for five years in a locked cupboard/filing cabinet at the School of Animal, plant and Environmental Sciences at the University of the Witwatersrand; electronic information will be stored on a password-protected computer.

This study has received written approval from the Human Research Ethics Review Committee of the University of the Witwatersrand under protocol number H15/11/29 should you require any further information or want to contact the researcher about any aspect of this study, please contact Ms, Tlou Daisy Raphela on 0721084987, Madeizen@gmail.com.

Should you have concerns about the way in which the research has been conducted, you may contact Prof. Neville Pillay on (011) 717 6459; Neville.Pillay@wits.ac.za.

Thank you for taking time to read this information sheet and for participating in this study.

Appendix III: Farmers questionnaire survey

Questionnaire Survey: Farmers

Interviewer(s): ____________________________________ Date: __________________

Farm Name/ Number____________Storage facility Name/Number_______________

Farm distance from the Reserve (km)____

Farm altitude____

GPS coordinate S________________________________E_________________________

Section A: Demographic Background

1. Sex? Male: □ Female: □

2. What is your highest level of education?

Grade 0-3: □ Grade 4-6: □ Grade 7-9: □ Grade 10-12: □ Tertiary Education: □

3.What is the main source of income in your homestead? Farming: □ Employed by the park: □ Unemployed: □ hunting: □ Craft making: □ other: □

If other (please specify) ___________________________________

4. What is your first language? Zulu: □ Swati: □ Sotho: □ other: □

If other (please specify) ___________________________________

5. What is the total homestead income per month? <R500 □, R500- R1000 □, R1000- R5000 □, R5000- R10 000 □, >R10 000 □, No response □

6. How many people live in this homestead permanently? _____________________

Section B: Farm Attributes

7. Do you own this farm? Yes: □ No: □

8.How much of your land is actually cultivated ____________________________ (m^2)

9. Do you have a fence around your farm? Yes: □ No: □

10. What is your age or the age of the farm owner if you do not own this farm?

11. Which crops do you plant in your farm?

Crops common name	Scientific Name (***For office use)***

12. What do you harvest these crops for? Commercial (sell your crops): leisure: □ Subsistence: □ other: □ If other please (specify) ______________________________

Section C: Crop Damages

13.Do you experience crop raiding in your farm?

14. Do you store crops after harvest? Yes: □ No: □

15. Do animals damage your crops pre and post-harvest? Yes: □ No: □

16. If yes, which animals are involved in damaging your crops, which crops are damaged by these animals and what evidence makes you think so?

Animal/s responsible	**Crops** (*List multiple crops if applicable*)	**Evidence** (*e.g. bites*)
Rodents		
Vervet Monkeys		
Baboons		
Other (specify below)		

17. When does crop raiding occur in your farm/storage facility?

April-August: □ September-March: □ All year round: □

18. How often do raids occur in your farm in the most recent growing season?

1 to 4 times per week: □ > 4 times per month: □ Less often than 1 month: □ Never in the last 12 months: □

19. When, during the day, do animals usually raid your farm?

Morning: □ Mid-day: □ Afternoon: □ Night: □

20. What size of your farm usually gets damaged at a given time?

Approximately: □ less than half a m^2 □ half a m^2 □ $1m^2$ □ and a half m^2

Other (specify) ____

Section D: Mitigative Strategies

21. How do you deal with the animals that damage your crops pre and post-harvest?

Pesticides: □ Dead traps and snares: □ patrolling the farm/storage facility: □

Use of poisoning agents in food traps: □ other: □ If other (*please specify*) ____________

22. How effective are the above methods?

Effective: □ somewhat effective: □ Not effective at all: □

23. What do you do with the crops that are damaged?

Feed to livestock's: □ Dispose: □ Use: □ other: □ If other (*please specify*) ___________

24. Have you ever tried anything to stop animals raiding your farm/storage? If so, what?

Nothing: □ Electric fences: □ Shooting: □ Dogs: □ Killing: □ Trapping: □ other: □

If other, please explain____

25. Have you ever killed or injured problem animals in your farm/storage?

Yes: □ No: □ No response: □

Section E: Opinions and perceptions

26. If yes, please indicate how many have you killed, which species have you killed and the Method/s used to kill these animals.

Animal type killed	Number	Method/s

27. Has killing or injuring animals been effective as a way of reducing their raiding?

Not at all effective: □ somewhat effective: □ Very effective: □

28. How effective has killing or injuring animals been in reducing crop raiding?

Not at all effective: □ somewhat effective: □ Very effective: □

29. What do you think are causes of crop raiding in your farm?

Neighbouring the park: □ Increased habitat destruction: □ Poor guarding methods: □ Lack of grazing land: □

30. How much do your crops pre and post-harvest contribute to your homestead basket?

≤30% of food: □ 31%-60%: □ 61%-90%: □ 91%-100%: □: Nothing: □

31. Do you think people's livelihoods in this community have been affected by crop raiding?

Yes: □ No: □

If yes how? Food security: □ Leisure time for individuals: □ homestead income: □ Children not going to school: □ Social relationships amongst neighbours: □ Other: □

If other (*please specify*) ___________________________

32. What are the social problems experienced in your community?

Food shortages: □ Low income: □ Poor relationships with neighbours: □ other: □ If other (*please specify*) ___________________________.

All answers will be kept confidential.

Thank you for your time!!!

The views of conservation practitioners on crop raiding adjacent to the Hluhluwe Game Reserve, South Africa

Abstract

The views of conservationists on human-wildlife conflict are central to the management and protection of wildlife. Here, I solicited the perceptions and opinions of conservationists about the occurrence of crop raiding by wildlife on farms adjacent to the Hluhluwe Game Reserve, in northern KwaZulu-Natal Province, South Africa. I considered whether their views were shaped by demographic factors (i.e. level of education, sex, language, ethnicity, religion and their position). I also asked the conservationists about the existence of community outreach programmes. Data were collected using a semi-structured questionnaire surveys from 35 people employed in conservation at the reserve. The conservationists mentioned that smaller, more ubiquitous and more persistent animals (i.e. insects, rodents and free-living birds) were the most important crop raiders. In addition, bush pig (*Potamochoerus larvatus*) was reported by many conservationists as crop raiders. The opinions of the conservationists did not always match those of the subsistence farmers obtained in an earlier study. In addition, the reports of animals escaping from the reserve (i.e. mostly African wild dog; *Lycaon pictus*) did not match the reports of crop raiding animals reported (mostly bush pig). Almost all (34) respondents reported that there was retaliation on wildlife by farmers. The organisational position held by conservationists had a significant effect on responses to four crop raiding related questions. Community liaison officers had contradictory responses to the other conservationists. Overall, most conservationists reported that the reserve had not implemented community outreach programmes (i.e. Community engagement programme; Environmental Education programme and Community Based Natural Resource Management Programme) at the time of my study, with only one mid-level employee reporting the implementation of Community Based Natural Resource Management programme. This shows that community outreach programmes were not high priority for the reserve. My study has shown that conservationists reported that wildlife do crop raid and farmers retaliate; yet the reserve was not supportive of a community co-management of wildlife.

Keywords: *conservationists, Hluhluwe Game Reserve, opinions, perception, wildlife*

Introduction

Protected areas are reported to be cornerstones for biodiversity conservation (Allendorf 2007; Walpole & Goodwin 2001) and are a major means of reducing loss of natural flora and fauna (Andam *et al*. 2008). The management of protected areas typically falls to conservationists to protect and manage the needs of wildlife (Alkan *et al.*, 2009). One issue that is of concern to conservationists is human-wildlife conflict experienced by farmers alongside protected areas (Shrestha & Alavalapati, 2006). For conservation to be successful, issues that drive conflict (e.g. crop raiding) around most conservation areas should also be addressed (Priston & Underdown,). In this regard, conservation efforts often falter because they fail to fully account for the diversity and multiple levels of human-wildlife conflict in conservation plans and actions (Madden, 2004).

Conservationists working in areas adjacent to rural subsistence farmers need knowledge on crop raiding issues because of the impact on the livelihoods of these farmers (Leong *et al*., 2009, 2011; Manolis *et al*., 2009), and concomitant retaliation by farmers on wildlife. Crop raiding is a concern for subsistence farmers in Africa and Asia (Khan & Bhagwat, 2010; Reed, 2008), and is a growing issue for South African subsistence farmers (Leong *et al*., 2009, 2011; Peterson & Colwell, 2013; Tedla *et al.*, 1999; Chapter 4 of this study). Yet, Hill (2000) believes that crop raiding is at the bottom of the list of conservation concerns in many developing countries. Hill *et al.* (2002) argued that prioritising farmers concerns, and understanding of human–wildlife interactions was central to developing effective human wildlife conflict mitigation.

While crop raiding by wildlife has been widely investigated (Hill, 1993, 2002; Naughton-Treves *et al.*, 2007; Naughton- Treves *et al*., 1998; Priston, 2001; Siex & Struhsaker, 1999), the focus has been less on the perceptions and opinions of conservationists as compared to those of farmers (Naughton-Treves, 1998; Priston, 2001; Siex & Struhsaker, 1999). Given the recurring nature of human-wildlife conflict in Africa, it is more than likely that conservationists are aware of such conflict (Hill, 2000; Horrocks & Baulu, 1994; Maples *et al*., 1976) and their views on this topic need to be solicited. For example, Seoraj-Pillai & Pillay (2016) assessed attitudes and opinions of conservation practitioners on human-wildlife conflict in northeastern South Africa, for both subsistence and commercial farmers and found mixed responses towards wildlife and local human communities by conservation practitioners who showed negative opinions about farmer retaliation and low tolerance for factors that threaten wildlife persistence.

The management of protected areas is often faced with the challenge of how to resolve human-wildlife conflict involving farmers (Heinen, 1993; Lehmkuhl *et al*., 1986; Maikhuri *et al*., 1997, 1998; McNeely, 1984). This is particularly necessary to validate claims of conflict, since farmers could exaggerate the extent of damage, hoping to obtain compensation from authorities (Naughton-Treves, 1996, 1997; Priston, 2001; Siex & Struhsaker, 1999; Sukumar, 1990). At the same time, conservationists' attitudes to crop raiding are also influenced by the need to safeguard compensation funds and this leaves a bitter feeling among farmers and erodes local tolerance for wildlife (Newmark *et al*. (1993) and Parry & Campbell et *al* (2002).

I investigated the opinions and perceptions of conservationists to crop raiding and issues surrounding crop-raiding behaviour of wildlife on subsistence homesteads around the Hluhluwe Game Reserve in the northern KwaZulu-Natal Province, South Africa. I focussed on the conservationists in the Hluhluwe Game Reserve because they were relevant to my study. I used a semi-structured questionnaire survey to probe issues directly related to crop raiding. Questionnaires were designed to probe issues about the crop-raiding animal species and which ones escape from the reserve. I also asked whether the neighbouring farming communities reported crop raiding by animals. In addition, I asked conservationists whether they experienced problem/issues inside the reserve that could be linked to retaliatory behaviour by farmers. Many studies on human-wildlife conflict reported that the demography of respondents often influenced their perceptions and opinions (De Boer & Baquete, 1988, Gillingham & Lee, 1999, Mehta & Heinen, 2001). Using ideas from several studies (e.g. Campbell *et al*., 2008; Gillingham & Lee, 1999; Pirta *et al*., 1997), I assessed several socio-demographic parameters of conservationists that are known predictors of their responses. These included their sex, home language, ethnicity, conservation position held, level of education, religion, formal education in conservation and number of years employed in conservation. These factors may shape the attitudes and opinions of conservationists towards crop raiding. For example, human attitudes toward crop raiding can be correlated with factors such as factual knowledge (Vaske *et al*., 2001; Zimmerman *et al*., 2005). Also demographic question, such as the number of years employed in conservation, can be an example of factual knowledge. In addition, I asked the conservationists whether the Hluhluwe Game Reserve had implemented community outreach programmes. I considered three over-arching questions in my study. 1. Assuming that the conservationists acknowledge that the wildlife crop raid farms, which animal species/type do they consider as most common crop-raiders and are these animals the same as those reported by farmers (see Chapter 4)? 2. Are the species that crop raid also those that escape from the reserve? In order to assess their awareness, conservationists were asked whether 3. The reserve had any environmental education programmes implemented at the time to gauge whether conservationists are in favour of community outreach programmes to mitigate human-wildlife conflict?

Material and methods

Study area

The questionnaire surveys were administered in the research centre of the Hluhluwe Game Reserve (28°00' S; 31° 43''E). The Hluhluwe Game Reserve has a high faunal diversity, which includes megaherbivores, such as rhinoceros (*Rhinocerotidae*), elephants (*Loxodonta africana*) and a wide spectrum of other herbivores (e.g. nyala (*Tragelaphus angasii*), springbok (*Antidorcas marsupialis*), blue wildebeest (*Connochaetes taurinus*), carnivores (e.g. lion (*Panthera leo*), African wild dog (*Lycaon pictus*), spotted hyena (*Crocuta crocuta*), primates, including vervet monkey (*Chlorocebus pygerythrus*) and chacma baboon (*Papio ursinus*), and various small mammals and birds (Balfour *et al.*, 2008; Infield, 1986; Owen-Smith, 1989).

The Hluhluwe–iMfolozi Park (HiP) is one of the biodiversity hotspots in northern KwaZulu-Natal Province, and plays a pivotal role in conserving the rich biodiversity of the Zululand region. The reserves' major objectives are biodiversity conservation and protection of wildlife (Infield, 1988). It was selected for the present study because of a historic (Infield, 1986) and prevailing human-wildlife conflict between neighbouring subsistence farming communities. The long-term monitoring of wildlife in the reserve shows a bias to mainly large mammals and species of conservation priority (e.g. black rhinoceros (*Diceros bicornis*), lion and African wild dog; Hayward *et al.*, 2006). Like most protected areas in South Africa, the HiP does not keep a database of non-priority animals, particularly small mammals (reserve manager Mr. Sihle Nxumalo, personal communication), possibly because of their cryptic nature, which requires labour intensive trapping (Avenant & Kuyler, 2002). Lack of record keeping of small mammals might not reveal whether and how these animals contribute to crop raiding, since their movement and activity are challenging to monitor, unlike that of larger mammals (Harcourt *et al*., 1986; Parry & Campbell *et al*., 1992).

Data collection and sampling procedure

Data collection for this study was limited to conservationists in the Hluhluwe Section of the Hluhluwe iMfolozi Park (HiP). Interviews are the most effective way to obtain detailed individual opinions and perceptions about an issue. Nonetheless, I am aware that interview-based approaches suffer from biases such as the researcher leading the respondent, respondent anticipation to please the researcher, pushing for concise answers (Mitchell & Slim, 1991), or discrepancies between what people report and what they actually feel or do (Mitchel & Slim, 1991). These weaknesses of the interviews were accounted for in the attached information sheet and consent forms (Appendices I and II), such as the clearly stating that the research was for educational purposes and there would be no compensation for participating.

Interviews were conducted in English and/or IsiZulu (the local language). The potential interviewees were asked whether they wanted to participate in the survey, and only if they agreed did the interview proceed. The purpose of the survey was explained to the potential interviewee. The identity of all respondents remained anonymous during this study as outlined in the conditions of my ethics permit. I gathered signed consent forms (Appendix I) from each respondent to participate in the study before conducting each survey.

The aims of the project were briefly explained to the potential interviewee. Interviews took 30 to 40 minutes to complete. The questions were both closed and open-ended and were aimed at extracting the respondent’s opinion on crop raiding by wildlife in neighbouring subsistence farmers. Each interviewee was informed that sensitive information and personal characteristics would not be included in any reports without his/her permission. In addition, an information sheet (Appendix II) with information about the research details was also read out to the interviewees. The survey took place over 3 months from March 2016 to May 2016. Questionnaire interviews were administered at the research centre on the reserve. Permission to collect data was sought from the University of the Witwatersrand Human Ethics Committee (protocol number H15/11/29) and from the Ezemvelo KZN Wildlife permits office (protocol number P27/2015).

Questionnaires structure and content

A semi-structured questionnaire (Appendix III), adapted from Seoraj-Pillai (2016), was used. The questionnaire was divided into three sections, including demographic information, perceptions and opinions of crop raiding by wildlife, and interactions of conservationists with neighbouring farming communities. The perception and opinion questions considered whether conservationists knew about conflicts in and around the reserve. Respondents who answered 'yes' to these questions were asked supplementary questions about the animal species that were reported. I also asked respondents whether animals escape from (left) the reserve. Finally, I asked respondents whether the reserve had implemented Community Engagement programmes (CEPs); Environmental Education Programmes (EEPs) and Community Based Natural Resource Management Programmes (CBNRMPs) at the time of the survey.

Questionnaire data capturing

I captured the data in Microsoft Excel. Predetermined numerical codes were assigned to responses to code them for processing and analysis. Each questionnaire response was captured in a separate worksheet of the excel file renamed by question number in the questionnaires. For example, responses for question number 3 for sex were entered in the same worksheet for all the questionnaires sampled and assigned numerical codes 1 for male and 2 for female. Questions that were not answered in the survey were considered non-responses. A separate worksheet was created with the questions and column headings, indicating the actual response, the respondent's number from 1 to 35, and the code of the response and the definitions of the codes. Multivalent responses were split into separate cells in consecutive rows; for example, if a respondent indicated that grazing, poaching and tree cutting were problems/issues inside the reserve, each problem/issue appeared on a separate row, and the respondent's number was repeated for answer. Most of the questions allowed for dichotomous answers, coded as yes and no.

Data analysis

I used Chi-squared tests (χ^2) of independence to analyse whether there were differences between the responses ('yes', 'no', 'not sure/do not know') for each of the eight demographic variables and the responses to the four opinion and perception questions (Questions 9, 11, 13 and 15; Appendix III). Using Chi-squared tests (χ^2) tests of independence, I also analysed the type of response (yes or no) to the question about whether the reserve had implemented any community outreach programmes, such as environmental education (EEPs), community based natural resource management (CBNRMPs) and community engagement programmes (CEPs). For all statistical tests performed, I reported the χ^2 statistics, degrees of freedom (*df*) and the P-values. Statistical analyses were performed using R statistical software v3.3.3, 2017: https://cran.rproject.org). All graphs were produced using a ggplot2 package from the R software.

Results

Socio-demographic characteristics of the respondents

I administered semi-structured interview-based questionnaires to all 35 conservationists (Conservationists (i.e. people who advocate or act for the protection and preservation of the environment and wildlife) employed by the Hluhluwe Game Reserve (> 18yrs of age) which included an ecologist (n = 1), field technician (n = 1), reserve manager (n = 1), animal monitor (n = 1), community liaison officers (n = 7), fence patrollers (n = 6), section rangers (n = 4), and field rangers (n = 14) that resided and worked inside the reserve. There were significant differences in the socio-demographic factors (Table 5.1) for most factors except the number of years employed in conservation and formal qualification in conservation (Table 5.1). Most respondents were black African (n = 32), Zulu speaking males (n = 31) and female (n = 1), there were only three white males amongst the respondents (Table 5.1). The majority of the respondents (n = 23) had high school education and above, from grade 7 up to tertiary education. Years working in conservation ranged from 5 to 37 years, with the majority (n = 19) of the respondents reporting to be employed in conservation for more than 10 years, and 15 of the respondents had qualifications in conservation (Table 5.1).

Table 5.1. Socio-demographic characteristics of conservationists in Reserve, South Africa. Significant statistics are shown in bold.

Parameters	**Responses**	**Chi-squared statistics**		
		$\chi 2$	*df*	**P-value**
Position	Ecologist =1	**33**	**7**	**< 0.001**
	Field technician =1			
	Reserve manager =1			
	Animal monitor =1			
	Community liaison officers =7			
	Fence patrollers =6			
	Section rangers =4			
	Feld rangers =14			
Ethnicity	Black =32	**24**	**1**	**< 0.001**
	White =3			
Language	Zulu =32	**48**	**2**	**< 0.001**
	English =2			
	Afrikaans =1			
Sex	Male =34	**20**	**1**	**< 0.001**
	Female =1			
Education	Grade 0-3 =9	**10**	**4**	**0.031**
	Grade 4-6 =3			
	Grade 7-9 =2			
	Grade 10-12 =9			
	Tertiary Education =12			
Religion	Christian =34	**31**	**1**	**< 0.001**
	Muslim =1			
Years working in conservation	Less than or equals to 10 years =16	5	17	0.995
	More than ten years =19			
Formal qualification in conservation	Yes =15	0.7	1	0.398
	No =20			

Perception and opinions about crop raiding

I analysed the responses ('yes', 'no', not sure/do not know/no responses) of conservationists to four questions from section B of the questionnaire (Appendix III), as detailed below.

Do you experience general problems/issues in and around your reserve?

I asked respondents whether they knew of any anthropogenic and crop-raiding problems in and around the reserve. Only one, a fence patroller, out of 35 respondents did not know of any problems/issues in and around the reserve, which was significantly different to chance ($\chi^2 = 31$, df = 1, $P < 0.001$). I then asked which problems/issues they knew about in and around the reserve from a list of possible problems. Of the 34 respondents who reported problems, 34 (97%) indicated hunting by the local communities, 32 (94%) indicated poaching, 31 (91%) diseases, 30 (88%) crop raiding by wildlife and domestic live-stock, 15 (41%) indicated collection of fuelwood by the local communities, 13 (38%) indicated grazing by domestic and live-stock and fires, 7 (20%) cutting of trees by the local communities and 1 (3%) indicated trespassing (Figure 5.1). There were significant differences in number of yes and no responses for hunting, poaching, diseases, crop raiding, cutting trees and trespassing, whereas no significant differences were found in conservationists' responses for collection of fuelwood, grazing and fires (Figure 5.1; Table 5.2).

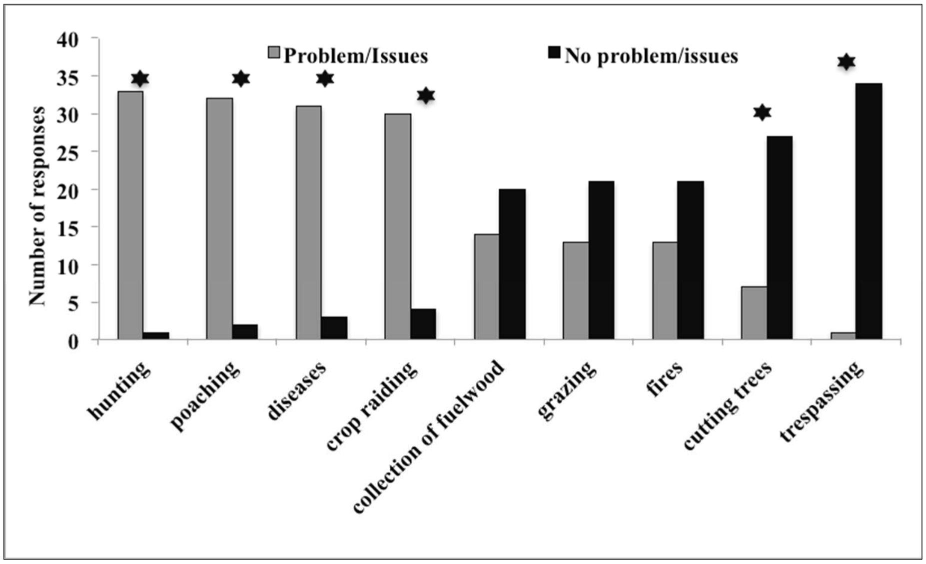

Figure 5.1. The number of conservationists that did and did not report issues/problems concerning the local farming communities at the edge of the Hluhluwe Game Reserve boundary, South Africa. Asterisks above bars show significant differences between conservationists that reported particular issue/problem vs those that did not report that particular issue/problem.

Table 5.2. Results of Chi-squared analyses for the responses of conservationists to the question 'which problem/issues are you aware of in and around the reserve?' Significant values are shown in bold.

Question	**Problems/Issues**	**Chi-squared results**		
		$\chi2$	***Df***	**P-value**
Which problems/issues are you aware of in and around the reserve?	Collecting fuelwood	0.7	1	0.398
	Crop raiding	**17.8**	**1**	**<0.001**
	Cutting trees	**12.6**	**1**	**<0.001**
	Diseases	**20.8**	**1**	**<0.001**
	Fires	2.3	1	0.128
	Grazing	2.3	1	0.128
	Hunting	**31.1**	**1**	**<0.001**
	Poaching	**24.0**	**1**	**<0.001**
	Trespassing	**31.1**	**1**	**<0.001**

Crop raiding animals

Conservationists were asked whether they thought that wildlife raid crops of adjacent farmers. In total, 31 of 35 respondents (88%) responded 'yes' and 4 of the respondents (12%) responded 'no' ($\chi^2 = 17$, df = 1, P < 0.001). I next asked which animals they thought raided crops from a list of possible raiders; space was provided for the respondents to add any animal that was not on the list. Of the 31 respondents, 30 (97%) of the respondents reported free-living birds and insects, 29 (94%) reported rodents, 27 (87%) reported bush pig (*Potamochoerus larvatus*), 22 (70%) warthog (*Phacochoerus africanus*), 19 (65%) chacma baboon (*Papio ursinus*), 17 (55%) vervet monkey (*Chlorocebus pygerythrus*), 2 (6%) reported elephant (*Loxodonta africana*) as culprits. Seventeen (55%) respondents reported domestic goat (*Capra aegagrus hircus*) and 10 (32%) domestic pig (*Sus scrofa domesticus*) as crop raiders in addition to wildlife crop raiders (Figure 5.2).

There were significant differences in the number of yes and no responses for free-living birds, insects, rodents, bush pig, warthog, domestic pig and elephant, whereas no significant differences in responses for domestic goat, vervet monkey and chacma baboon were found (Figure 5.2; Table 5.3).

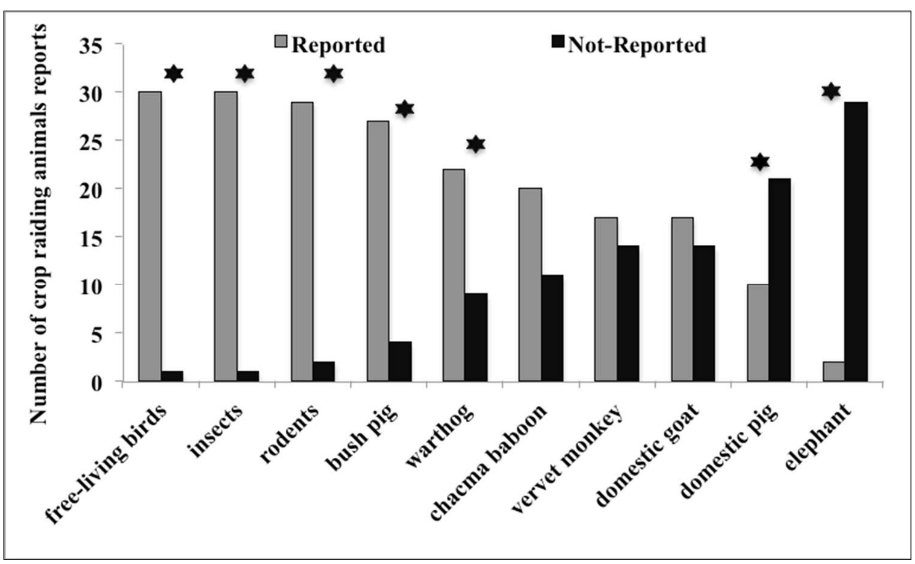

Figure 5.2. The number of conservationists that did and did not report potential crop raiding animals at the edge of the Hluhluwe Game Reserve boundary, South Africa. Asterisks above bars show significant differences between conservationists that reported a particular crop raiding animal type vs those that did not report that animal type.

Table 5.3. Results of Chi-squared test analysing the responses of conservationists to the question 'Which animals raid crops of adjacent farmers?' Significance values are shown in bold.

Question	Responses	Chi-squared statistics		
		$\chi2$	*Df*	P-value
Which animals raid crops of adjacent farmers?'	Bush pig	**17.0**	**1**	**<0.001**
	Chacma baboon	2.6	1	0.106
	Elephant	**23.5**	**1**	**<0.001**
	Warthog	**5.4**	**1**	**0.019**
	Vervet monkey	0.2	1	0.590
	Rodents	**23.5**	**1**	**<0.001**
	Free-living birds	**27.1**	**1**	**<0.001**
	Insects	**27.1**	**1**	**<0.001**
	Domestic goat	0.2	1	0.590
	Domestic pig	**3.9**	**1**	**0.048**

Do neighbouring communities report crop-raiding animals?

Of the 35 respondents, 20 (57%) responded that neighbouring communities reported crop-raiding animals, 9 (25%) of the respondents answered no to this question, and 6 (17%) were not sure if the neighbouring community reported crop-raiding animals ($\chi^2 = 24$, df = 2, P < 0.001). Of the 20 respondents that reported that neighbouring communities do report crop raiding animals, 20 (100%) reported bush pig (*Potamochoerus larvatus*, 19 (95%) African wild dog (*Lycaon pictus*), 18 (90%) warthog (*Phacochoerus africanus*), 16 (80%) lion (*Panthera leo*), 12 (60%) vervet monkey and porcupine (*Hystrix africaeaustralis*), 8 (40%) chacma baboon (*Papio ursinus*) and 2 (10%) reported elephant (*Loxodonta africana*) as culprits (Figure 5.3).

There were significant differences in the number of yes and no responses for African wild dog, warthog, lion and elephant, whereas no significant difference was found in the number of responses for bush pig, vervet monkey, porcupine and chacma baboon (Figure 5.3; Table 5.4).

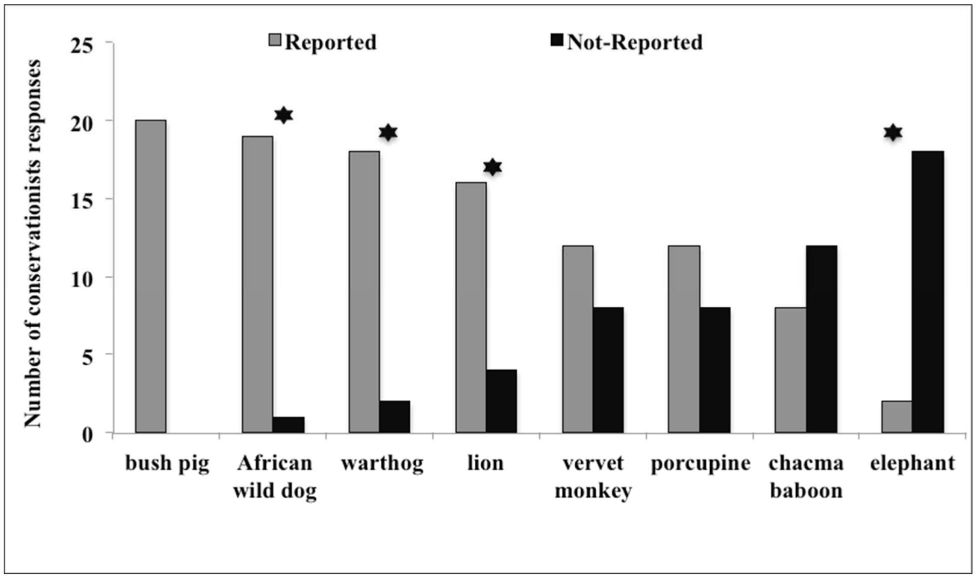

Figure 5.3. The number of conservationists that did and did not report crop raiding animals reported by neighbouring subsistence community at the edge of the Hluhluwe Game Reserve, South Africa. Asterisks above bars show significant differences between conservationists that reported a particular crop raiding animal type vs those that did not report that animal type.

Table 5.4. Results of Chi-squared statistics analysing the responses of conservationists to the question 'Do neighbouring communities report crop raiding animals?' Significant values are shown in bold.

Question	**Animals**	**Chi-squared statistics**		
		χ2	***Df***	**P-value**
Which animals do neighbouring communities report crop-raiding?	African wild dog	**7.08**	**1**	**<0.001**
	Bush pig	16.2	1	0.081
	Chacma baboon	0.8	1	0.371
	Elephant	**12.8**	**1**	**<0.001**
	Lion	**7.2**	**1**	**0.007**
	Porcupine	0.8	1	0.371
	Vervet monkey	0.8	1	0.371
	Warthog	**12.8**	**1**	**0.000**

Animal species leaving the reserve

In total, 22 of 35 respondents (63%) answered 'yes' and 9 (26%) answered 'no' ($\chi^2 = 30.4$, df = 2, $P < 0.001$) to animals leaving the reserve. Four respondents (11%) chose not to respond to this question. The 22 respondents who indicated that animals did escape from the reserve were asked to list these animal species. 18 (81%) respondents reported African wild dog, 16 (72%) warthog, 13 (59%) chacma baboon, 8 (36%) vervet monkey and 2 (9%) reported elephant. There were significant differences in the number of yes and no responses for African wild dog, warthog and elephant, whereas no significant difference was found in the number of responses for chacma baboon and vervet monkey (Figure 5.4; Table 5.5).

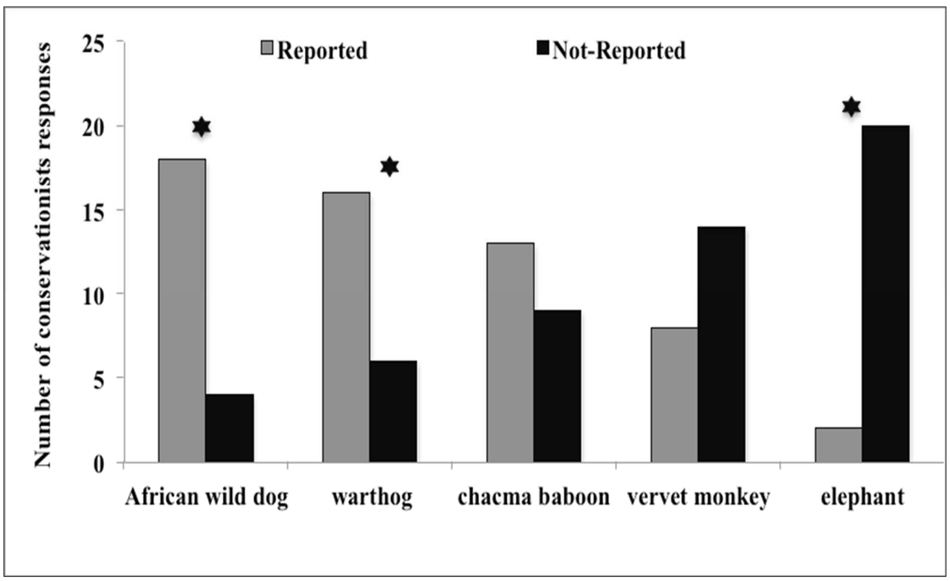

Figure 5.4. The number of conservationists that did and did not report the raiding animals of Hluhluwe Game Reserve in South Africa that escape from the reserve. Asterisks above bars show significant differences between conservationists that reported a particular raiding animal type that escape from the reserve vs those that did not report that animal type.

Table 5.5. Results of Chi-squared statistics analysing the responses of conservationists to the question 'do animal species leave the reserve?' Significant values are shown in bold.

Question	Animals	Chi-squared statistics		
		$\chi 2$	*df*	P-value
Do animal species leave the reserve?	African wild dog	**4.5**	**1**	**0.033**
	Chacma baboon	0.7	1	0.393
	Elephant	**14.7**	**1**	**<0.001**
	Vervet monkey	1.6	1	0.200
	Warthog	**4.5**	**1**	**0.033**

Demographic correlations

I considered the conservationists' responses to four questions posed (question number 9,11,13 and 15; See Appendix III) and used Chi-squared test (χ^2) statistics to analyse the relationship between responses (yes/no/not sure) for these questions against demographic variables (sex, language, level of education, position, ethnicity and religion). I excluded two demographic variables (i.e. formal qualification in conservation and years working in conservation) in the analysis since no significant differences were found in conservationists' responses for these variables (Table 5.1). Based on the four questions posed the 'yes' responses indicated a positive opinion and 'no' responses represented a negative opinion towards crop raiding and issues related to crop raiding. No significant differences were found for language (χ^2 = 2.25, df = 4, P = 0.690), sex (χ^2 = 1.40, df = 2, P = 0.495), ethnicity (χ^2 = 2.26, df = 1, P = 0.098), religion (χ^2 = 0.47, df = 1, P = 0.042) and the level of education (χ^2 = 7.49, df = 8, P = 0.439). However, there was a significant difference in responses in respect of position (χ^2 = 26.48, df = 14, P = 0.022). For all four questions, the number of yes responses (n = 33) for community liaison officers were higher compared to the number of yes responses of other employees of Hluhluwe Game Reserve: field rangers, (n = 28), ecologists (n = 3), fence patrollers (n = 13), field technician (n = 2), reserve manager (n = 3), section rangers (n = 13 and wild dog monitors (n = 2).

Interaction of conservationists with the neighbouring community

I specifically asked the conservationists whether the reserve had implemented any community outreach programmes, such as environmental education (EEPs), community based natural resource management (CBNRMPs) and community engagement programmes (CEPs). Of the 35 respondents that answered these questions, 16 (46%) answered yes and 19 (54%) answered no to the implementation of EEPs ($\chi^2 = 0.26$, df = 1, P = 0.612). For CEPs, 15 (43%) answered yes and 20 (57%) answered no to the implementation ($\chi^2 = 0.70$, df = 1, P = 0.398). For CBNRMPs, 1 (3%) respondent in a mid-level position answered yes and 34 (97%) answered no to the implementation ($\chi^2 = 31.10$, df = 1, P < 0.001).

Discussion

I investigated the perceptions and opinions of conservationists employed in different positions at the Hluhluwe Game Reserve on crop raiding issues. Thirty out of 35 conservationists reported incidences of crop raiding. In addition to crop raiding, conservationists reported illegal hunting and poaching as the leading issues experienced inside the reserve.

The conservationists mentioned that smaller, more ubiquitous and more persistent animals (i.e. insects, rodents and free-living birds) as the most important crop raiders outside the reserve, consistent with other human-wildlife conflict studies in Africa (Adesina *et al*., 1994; Chitere & Omolo, 1993; Goldman, 1987; Hill, 1997; Naughton-Treves, 1998). Surprisingly, elephant (*Loxodonta africana*) was not considered as a crop raider by most conservationists in contrast to many of human-wildlife conflict studies elsewhere (Hill, 1997; Mwakatobe *et al*., 2014; Naughton-Treves *et al*., 1998). However, bush pig (*Potamochoerus larvatus*) was perceived as the most important mammal crop raider by conservationists. This was not surprising since the literature on human-wildlife conflict mentioned the bush pig as a formidable crop raider across Africa (Gillingham & Lee, 1999; Newmark *et al*., 1994; Naughton-Treves, 1997), such as near Kasungu, Malawi (Gillingham & Lee, 1999) Manyara National Park and Selous Game Reserve, Tanzania (Newmark *et al*., 1994), Kibale National Park, Uganda (Naughton-Treves, 1997), Upper Lupande Forest, Zambia (Lubilo & Child, 2010), and Budongo Forest reserve, Uganda (Hsiao *et al*., 2013).

Historically, the farming community around the Hluhluwe Game Reserve reported bush pig (*Potamochoerus larvatus*), chacma baboon (*Papio ursinus*), elephant (*Loxodonta* *africana*), vervet monkey (*Chlorocebus pygerythrus*) and warthog (*Phacochoerus africanus*) to conservationists as being crop-raiding culprits, overlapping with the perceptions of conservationists. In contrast to conservationists' reports about crop raiding animals, the neighbouring community apparently also reported porcupine (*Hystrix africaeaustralis*) as a crop raider. All these species are notorious crop raiders elsewhere in Africa. (Gunn *et al*., 2014; Hill, 2000; Naughton-Treves *et al*., 1998; Seoraj-Pillai & Pillay, 2016; Tweheyo *et al*., 2005). For example, Gunn *et al*. (2014) reported crop-raiding by elephants around Mikumi National Park in Tanzania, Tweheyo *et al*. (2005) reported bush big and porcupine as the major crop pests around Budongo Forest reserve in Uganda, and crop raiding by primates has been extensively studied in Africa (Hill, 2000; Naughton-Treves *et al*., 1998; Tweheyo *et al*., 2005).

Surprisingly, the conservationists also mentioned farmers reporting lion (*Panthera leo*), African wild dog (*Lycaon pictus*) as being crop raiders. This might be that opinions of crop raiding might have been conflated with general wildlife conflict. In particular, African wild dogs were reported to regularly leave the reserve and are sometimes implicated in conflicts where they occur (Gusset *et al*., 2009). Interestingly, Sillero-Zubiri *et al*. (2007) added to the definition of crop raiding to include trampling of crops by wildlife, but whether this applies to African wild dogs is not known.

Many respondents reported African wild dog as leaving the reserve. Competition and predation by larger carnivores may be one of the reasons African wild dogs of Hluhluwe – iMfolozi Park complex constantly escape from the reserve onto neighbouring rural communities (Macdonald & Frame, 1998). Similarly, African wild dogs were also reported to escape from Pilanesberg National Park South Africa (Van Dyk & Slotow, 2003).

Generally, human perceptions of crop raiding, especially wildlife perceived to be responsible for crop damage is often contradictory (Linkie *et al*., 2007). Bush pig was a crop raider according to conservationists and neighbouring communities. Yet, bush pig was never reported as leaving the reserve by conservationists, which was in contrast to reports of escaping African wild dogs. There could be several reasons for conservationists not reporting bush pig escaping from the reserve and why African wild dog was never reported as crop raiding by conservationists. 1) Bush pigs may forage on their own or in small family groups. Furthermore, bush pigs are nocturnal foragers (Ghiglieri *et al*., 1982) compared to the pack hunting of African wild dogs (Creel & Creel, 1995), such that bush pigs leaving the reserve might be less noticeable than a pack of African wild dogs. 2) In this study, the majority of the respondents (58%) were generally positive towards wild dogs, and therefore the conservationists' responses in my study might have been based on the outcome of that study. 3) The opinions of the conservationists might reflect their shared opinions on selected species, such that reports might not reflect independent assessment.

Surprisingly and in contrast to many studies where elephants and farmers overlap throughout Africa, only two conservationists reported elephants as crop raiders and, escaping from the reserve. Elephants have been reported to be the most destructive wildlife in Tanzania (Kaswamila, 2007; Ntalwila *et al*., 2003; Mwakatobe *et al*., 2014). Slotow (2012) reported that boundary fencing prevents human-elephant conflict except when maintenance has been neglected. During my study, the Hluhluwe Game Reserve was refenced; this could be the main reason why there were no elephant problems outside the Hluhluwe Game Reserve.

I found that demographic variables among Hluhluwe Game Reserve conservationists played a lesser role in predicting perceptions and opinions of conservationists, unlike elsewhere in Africa (Gadd, 2005; Hill, 1998; Infield, 1988; Tweheyo *et al*., 2005). For example, Gadd (2005) reported various demographic variables (i.e. sex, level of education and language) to influence opinions and perceptions of conservationists in Laikipia, Kenya. The position held by conservationists in the reserve was the only significant demographic variable associated with responses to the questions concerning crop raiding in my study. I interviewed people employed as ecologists, field technicians, the reserve manager, animal monitor, community liaison officers, fence patrollers, section rangers and field rangers. The numbers of 'yes' responses for community liaison officers were the highest compared to the other employees. This showed that the community liaison officers of Hluhluwe Game Reserve were aware of the occurrence of crop raiding behaviour by wildlife.

The overall numbers of 'no' responses were higher than the overall number of 'yes' responses when conservationists were asked whether the reserve had implemented community outreach programmes (i.e. Environmental Education Programmes, Community Based Natural Resource Management Programmes and Community Engagement Programmes). Only one mid-level position employee responded yes to the implementation of Community Based Natural Resource Management Programme. This finding shows that the community engagement programmes are not high priority in the reserve. In Hluhluwe Game Reserve, the approach to protected area management has historically been to protect the reserve from illegal activities through patrols rather than engage in community outreach (Infield & Namara, 2001).

In conclusion, I found contradictions in the perceptions and opinions of Hluhluwe Game Reserve conservationists in that the animals perceived as crop raiders were not often the ones escaping from the reserve. Despite reports that bush pig may be a formidable crop raider around the Hluhluwe Game Reserve, this animal was not reported to leave the reserve by conservationists. African wild dog and lion were reported to conservationists by the neighbouring community as crop raiders, for unknown reasons, but possibly related to their conservation status and potential to cause livestock loss. Furthermore, many conservationists reported no implementation of community outreach programmes. I suspect that the responses of Hluhluwe Game Reserve conservationists might reflect a collective or shared opinion which was evident in the contradictory responses to questions related to crop raiding animals and those leaving the reserve. Nonetheless, my study has contributed to our understanding of the perceptions and opinions of conservationists to human-wildlife conflict generally and in a subsistence farming community specifically.

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Appendix I: Consent form-Conservationist survey

UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCE

Date: ________________________
Questionnaire number______________________ Farm/storage number____________

I, __________________ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, and anticipated inconvenience of participation.
I have read (or had explained to me) and understood the study as explained in the information sheet. I have had sufficient opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary and that I am free to withdraw at any time without penalty.

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, and there are no benefits in participating in this study, but that my participation will be kept confidential unless otherwise specified or permission is sought from me.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname: ____

Participant Signature: _____________________Date: _______________________

Researcher's Name & Surname: ____

Researcher's Signature: ___________________Date: _______________________

Appendix II: Information sheet-Conservationists survey

UNIVERSITY OF THE WITWATERSRAND
SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCE
CROP RAIDING ON SUBSISTENCE FARMERS CONSERVATIONISTS SURVEY

I am conducting a research study to find out your opinions and perceptions toward crop raiding by wildlife from your Game Reserve, and I will like you to participate in this questionnaire survey for my PhD study. My research study seeks to investigate your opinions and perceptions on crop raiding and issues related to crop raiding.

You are chosen from the list of employees based on the fact that you have been working for Hluhluwe Game Reserve for more than 5 years. Should you agree to participate in my study, I will be asking you demographic information and crop raiding related questions all of which will be in a questionnaire format, which will be read out to you at the Hluhluwe Research centre at the time that is convenient for you.

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason. This study is solemnly intended for a PhD thesis. Therefore, there will be no payment or reward for participation. Any participant throughout their participation in the study will incur no cost in monetary value or otherwise.

Feedback on the findings of this project will be made available through the Hluhluwe Game Reserve research Centre. All information gathered by this survey will be kept confidential until it is analysed. Your answers will be given a code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings. Otherwise, records that identify you will be available only to people working on the study. The researcher will store hard copies of your answers for a period of five years in a locked cupboard/filing cabinet at the School of Animal, Plant and Environmental Sciences at the University of the Witwatersrand and electronic information will be stored on a password protected computer.

This study has received written approval from the Human Research Ethics Review Committee of the University of the Witwatersrand under protocol number H17/11/29 and from the Ezemvelo KZN wildlife permits office protocol number P27/2015. Should you

require any further information or want to contact the researcher about any aspect of this study, please contact Tlou Daisy Raphela on 0721084987, Madeizen@gmail.com.
Should you have concerns about the way in which the research has been conducted, you may contact Prof. Neville Pillay on (011) 717 6459; Neville.Pillay@wits.ac.za

Thank you in advance for taking time to read this information sheet and for participating in this study.

Appendix III: Conservationists questionnaire survey

Interviewer(s): ___________________________________ Date: __________________

Please answer where applicable

Section A: Conservationists Demographics

1. What is your position in Hluhluwe Game Reserve?

Fence patrollers: □ Ecologist: □ Reserve Manager: □ Field technician: □

Section ranger: □ Field ranger: □ Community liaison officer: □

If other (please specify____

2. What is your first language?

Zulu: □ Swati: □ Sotho: □ English: □ Afrikaans: □ other: □

If other (please specify) ____

3.Sex? Male: □ Female: □

4.What is your highest level of education? Grade 0-3: □ Grade 4-6: □ Grade 7-9: □ Grade 10-12: □ Tertiary Education: □

5. What is your ethnicity Black □ White □

6. What is your religion Christian □ Muslim □ other □

7. Do you have any formal qualifications related to your position/conservation? Yes □ No □ No response □

8.How long have you worked in conservation? ___________Years _____________Months

Section B: Perceptions and opinions on crop raiding

9. Do you know of any problem/ condition in and around the reserve?

10. If yes, which of the following conditions/problems do you know in and around the reserve?

Collection of fuelwood □ crop raiding □ cutting of trees □

disease/ parasites □ fires □ grazing □ hunting □

Poaching □ other □ (specify): ____

11. Do you think animals raid crops of adjacent farms? Yes □ No □ no response/unsure □

12. Which of the following animals do you think raid crops of adjacent farms?

Animal Species	**Tick (x) accordingly**
Chacma baboons	
Black Rhino	
Lion	
Leopards	
Wild dog	
Hyena	
Elephants	
Warthog	
Monkeys	
Warthog	
Bushpig	
Other (specify below)	

13. Do neighbouring communities report crop raiding animals when they see them?

14. Which animals are mostly reported to raid crops of neighbouring farms?

15. Do animals leave the reserve to raid crops of neighbouring communities? Yes ☐ No ☐ Do not know ☐

16. If yes which animals leave the reserve?

Section C: Interaction of conservationists with neighbouring farming communities

17. Does your reserve have any environmental education programmes implemented currently?

Yes: ☐ No: ☐

18. Does your reserve have any community based natural resource management programmes implemented currently? Yes: ☐ No: ☐

19. Does your reserve have any community engagement programmes implemented currently?

Yes: □ No: □

All answers will be kept confidential.

Thank you for your time!!!

Crop raiding on homestead food security of subsistence farmers on the edge of the Hluhluwe Game Reserve, South Africa

Abstract

Worldwide, subsistence farmers have expressed concerns about food shortage due to crop raiding by wildlife. However, the relationship between crop raiding and food security of small-scale farmers is not well studied. I investigated the effects of crop raiding on homestead food security in subsistence farming homesteads on the edge of the Hluhluwe Game Reserve in northern KwaZulu-Natal, South Africa. I used data collected during previous field inspections of 20 farms and from questionnaire surveys of resident farmers (Chapters 3 and 4). I firstly assessed how crop loss influenced potential calorie and income loss. I secondly assessed homestead dietary diversity and relative energy and potential income losses as indicators of food insecurity. I compared these variables against two predictors of food security: homestead size and contribution of particular crop types to the food basket. The number of crops lost per farm was positively correlated with potential income loss but not potential calorie loss. Larger homesteads were more prone to food insecurity than smaller homesteads. The dietary diversity of larger homesteads was potentially reduced due to higher number of crops lost with the highest number lost being for spinach (*Spinacia oleracea*) as compared to all the other food crops damaged. Larger homesteads suffered a higher energy loss, especially in terms of maize (*Zea mays*). In addition, since maize contributed the highest (91%-100%) to the homestead food basket, larger homesteads were more vulnerable to food insecurity as compared to smaller homesteads. Generally, crop damage resulted in R2 427/annum (about US$180.71) potential loss in income, reducing homestead income by 16.18%, and this effect was high for larger than smaller homesteads. My results suggest that larger homesteads, particularly where maize contributes substantially to homestead food baskets are more prone to food insecurity in the rural subsistence farming community that I studied.

Keywords: *crop raiding*, *dietary diversity, food security*, *homestead size, subsistence homesteads*

Introduction

Crop raiding by wildlife contributes significantly to food insecurity of subsistence homesteads adjacent to protected areas (Nahonyo, 2001; Naughton-Treves *et al*., 1998; Ntiamoa-Baidu, 1997; Yudelman *et al*., 1998). Since subsistence homesteads depend mainly on crops they grow for their daily nutrients (Dupont & Thirlwell, 2009), a reduction in food supply could even result in starvation in these homesteads (Rosegrant & Cline, 2003). In addition, crop raiding might limit the range of crops that could be grown, consequently reducing the dietary diversity of these farmers (Ntiamoa-Baidu, 1997). Crop raiding could also have indirect consequences through reduced homestead incomes (Weladji & Tchamba, 2003), even if this is a comparatively small amount.

Cross & Altman (2010) maintained that the meaning of food security is not always obvious. The Food and Agricultural Organisation (FAO) defines food security as "The situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996:12). Thus, food insecurity is the failure to achieve this outcome. However, the predictors of food insecurity are multi-dimensional, involving political, economical and socio-environmental (Patel *et al*, 2009). Furthermore, the multiple factors that influence access to food are not well understood (Modi *et al*., 2006). Here, I focused on the socio-environmental issues associated with crop raiding by wildlife as a factor that affects food security of subsistence homesteads.

Historically, food gardens were thought to provide a means to overcome food insecurity (Marsh, 1998). Some countries, such as Japan and Indonesia, have successfully supported small-scale farming, which contribute to homestead food baskets (Altman *et al*., 2009). However, little is written about the difficulties experienced by these farmers between planting and harvesting in relation to crop pests (Brooks, 2005). Hart *et al*. (2010) reported that subsistence farming does not necessarily imply improved food security. For example, abiotic factors, such as drought, in synergy with biotic factors, such as crop raiding, can destroy the entire cultivation and food secure subsistence homesteads might transition to being food insecure easily (Aliber, 2009; Hart *et al*, 2010).

In Africa, crop raiding by wildlife is a major influence to subsistence farmers' food basket, both in terms of food and income loss (Naughton *et al*., 1999), as illustrated in the next few examples. Kaswamila *et al*. (2007) found that the impact of wildlife on crop damage in North-eastern Tanzania resulted in crop loss of maize (*Zea mays*), finger millet (*Eleusine coracana*) rice (*Oryza sativa*), common bean (*Phaseolus vulgaris*), banana (*Musa paradisiaca*) and lablab bean (*Lablab purpureus*) by an average 0.08 ton/annum, equivalent to two months homestead food, and reduced homestead income by 1.3%. In Western Rwanda on the Giswati forest boundary, substantial losses of crops were reported, with replacement costs possibly reaching 10–20% of total homestead income (McGuinness & Taylor, 2014). In Nigeria, Bukie *et al*. (2018) reported that crop raiding impacted the food security of subsistence farmers by affecting their potential income; the annual income loss was estimated between US$5.53 - 276.63 (which might represent a substantial loss).

While South Africa may be considered as a food secure country (Altman *et al*., 2009), large numbers of subsistence farming homesteads within the country might be food insecure (Altman *et al*., 2009; Rosegrant & Cline, 2003). In order to understand the homestead food security status in South Africa, it is necessary to investigate how the rural, poor subsistence homesteads adjacent to protected areas obtain food and the issues that affect their food security (Pinstrup-Andersen, 2009). Altman *et al*. (2009) reported that many agricultural crop production projects aiming to provide food and to generate income through sale of surplus produce are affected by crop raiding by wildlife in rural KwaZulu-Natal Province, South Africa. In addition, Misselhorn (2007) found an association between food security status and crop raiding and also between food security status and the number of people in homesteads in KwaZulu Natal Province. Homesteads with more people were found to have experienced higher number of raids and were also found to be more food insecure as compared to homesteads with less people (Misselhorn, 2007).

I aimed to investigate the effects of crop raiding by wildlife on homestead food security of subsistence farming homesteads adjacent to the Hluhluwe Game Reserve in KwaZulu-Natal Province, South Africa. I investigated food security status of these homesteads by using data obtained in a previous study (Chapter 2), in which I quantified the level of damage to four crops, beetroot (*Beta vulgaris*), common bean (*Phaseolus vulgaris*), maize (*Zea mays*), spinach (*Spinacia oleracea*), which were important food crops to subsistence farming in the area. I considered the interaction of five factors that are known to influence food security (Bareriga *et al*., 2010; Bukie *et al*., 2018; Kaswamila *et al*., 2007). These included homestead dietary diversity, relative energy loss, potential income loss, homestead size, crop types lost and the contribution of food crops to homestead food basket. Traditionally, homestead dietary diversity considers different food groups consumed

(Kanbur, 2003). Here, I focussed on the number of food crops lost for beetroot, common bean, maize and spinach per homestead because these crops were the most abundantly grown crops in this community. While I could not generate predictions *a priori* about the variables measured here, I expected to generate ideas on how crop raiding could contribute to food insecurity in terms of the loss of potential calories and potential income, such that homesteads that lost the most crops would be more vulnerable.

Materials and methods

I used data collected on 20 subsistence farms adjacent to the Hluhluwe Game Reserve. The data set was generated from results obtained from previous studies (Chapters 3 and 4), using direct field measurements and questionnaire survey data.

The FAO maintains that food security involves proper nutrition for a healthy life. Thus, I selected the five variables from my previous research that served as proxies for food security, including: 1) number of crops damaged of four important crop types, maize, beetroot, common bean, and spinach, which was quantified by counting the total number of damaged individual crop samples (i.e. leaves of beetroot, spinach and seeds of maize and common bean) in quadrats placed on 20 sampled farms (Chapter 3); 2) energy loss, estimated from the loss of the whole or part of the food plants (Chapter 3); 3) income loss, estimated from the loss of the whole or part of the food plants (Chapter 3); 4) homestead size obtained from questionnaire data (Chapter 4), divided into two categories: homesteads with 3-5 people (smaller homesteads) and homesteads with 6-8 people (larger homesteads) for statistical analysis; and 5) contribution of crop types to homestead food basket (hereafter crop contribution; Chapter 4). Crop contribution was measured as percentages in five categories (≤ 30% of food; 31%-60%; 61%-90%; 91%-100%). These five variables are reported to influence homestead food security of subsistence farmers (Aliber, 2009; Altman *et al.*, 2009; Ntiamoa-Baidu, 1997).

Data analysis

I analysed data using R statistical software (version 3.3.3, 2017). Statistical tests were two-tailed, and significance levels were set at P = 0.05. The data set did not meet the assumptions of normality (Shapiro-Wilk test), so I used nonparametric statistical tests.

I first analysed the relationship between the number of crops lost and the other predictors (relative calorie loss and potential income loss) using Spearman's rank analysis. This allowed me to assess a correlational relationship between crops lost and potential insecurity.

I next ran a series of Generalized linear models (GLM) to analyse how the number of crops lost, relative calorie and potential income loss per annum were influenced by factors known to influence homestead food security, namely crop type, homestead size and crop contribution. These analyses considered between farm variations to assess whether any of the predictors could be considered for food insecurity.

GLMs were run using the *glm* function with a Poisson distribution and Logit link function (lme4 package, Bates *et al*. 2015). The number of crops lost, relative calorie loss and potential income loss were analysed separately as response variables; crop type, homestead size and crop contribution (and their interactions) were set as main effect predictor variables. Crop contribution was not included as a predictor variable for potential income loss, because crop contribution would not have an effect on potential income loss. I used Fisher's LSD post hoc tests to identify the influences of the predictor variables on the dependent variables. For all models, I included farm size as a covariate to account for the potential farm size effect. When the covariate was significant, Spearman rank order correlation coefficient (i.e. Spearman rho) analyses was performed to investigate the relationship between farm size and the other predictors.

I checked the models fit for the variables described above, and used the most appropriate model based on the plot of the residuals against the fitted values from each model (Crawley, 2007). For all models, significance was determined using Wald (χ^2) statistics and P-values were generated by running the Anova of the model (Bates *et al*. 2015). All graphs were produced using a GGplot2 package from the R software.

Results

Crop loss vs calorie loss and income loss

The number of crops lost and relative calorie loss was not significant (r_s = 0.01; P = 0.830; Figure 6.1). The correlation coefficient indicated that 0.01% of the variance in the relative calorie loss was explained by the number of crops lost.

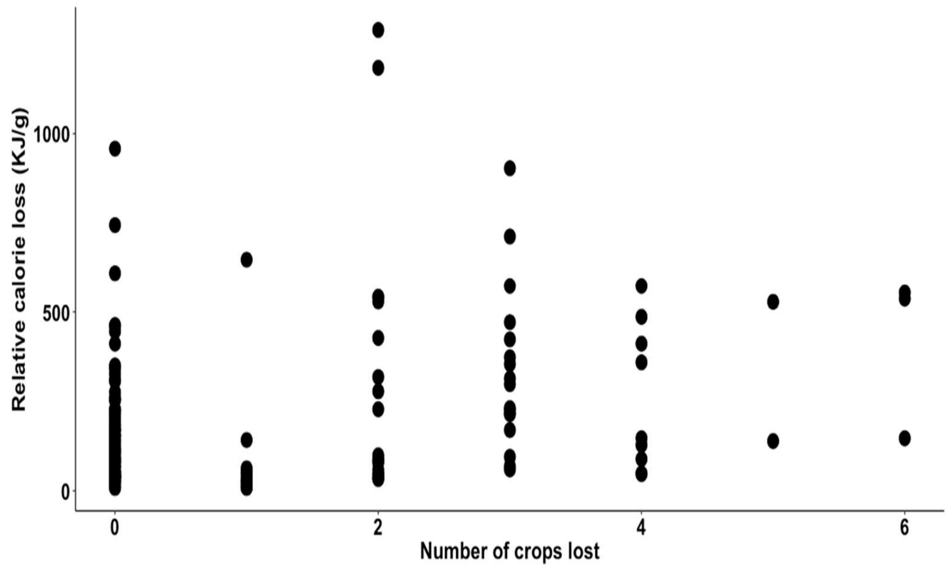

Figure 6.1 Scatterplot of the relationship between relative calorie loss and the number of crops lost at subsistence homesteads on the edge of Hluhluwe Game Reserve, South Africa.

A Spearman rank analyses showed a significantly positive relationship between the potential income loss and the number of crops lost ($r_s = 0.81$, $P < 0.001$; Figure 6.2). The effect size of this relationship was strong ($d = 0.8$; Cohen, 1988). Squaring the correlation coefficients indicated that 65.61% of the variance in the number of relative calorie loss was explained by the number of crops lost.

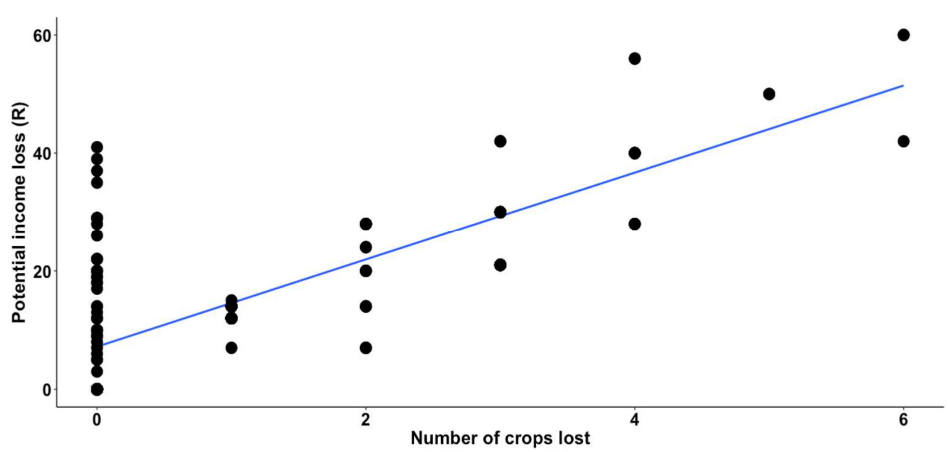

Figure 6.2. Scatterplot of the relationship between potential income loss and the number of crops lost at subsistence homesteads on the edge of Hluhluwe Game Reserve, South Africa. The trend line is significant.

Number of crops lost

Crop type (Wald χ^2_3 = 224.79, P < 0.001) and the interaction between homestead size and crop type (Wald χ^2_3 = 8.68, P = 0.033) were significant predictors of the number of crops lost, with a significantly higher loss of spinach followed by maize, beetroot and common bean, and significantly more spinach loss was recorded in larger homesteads compared to smaller homesteads (Figure 6.3). Homestead size (Wald χ^2_1 = 0.32, P = 0.571), crop contribution (Wald χ^2_1 = 0.39, P = 0.528), farm size (Wald χ^2_1 = 0.48, P = 0.488) and the interactions between homestead size and crop contribution (Wald χ^2_1 = 0.74, P = 0.386), crop type and crop contribution (Waldχ^2_3 = 5.26, P = 0.153) and the three way interaction between homestead size, crop type and crops contribution (Wald χ^2_3 = 0.00, P = 0.999) were not significant predictors of the number of crops lost.

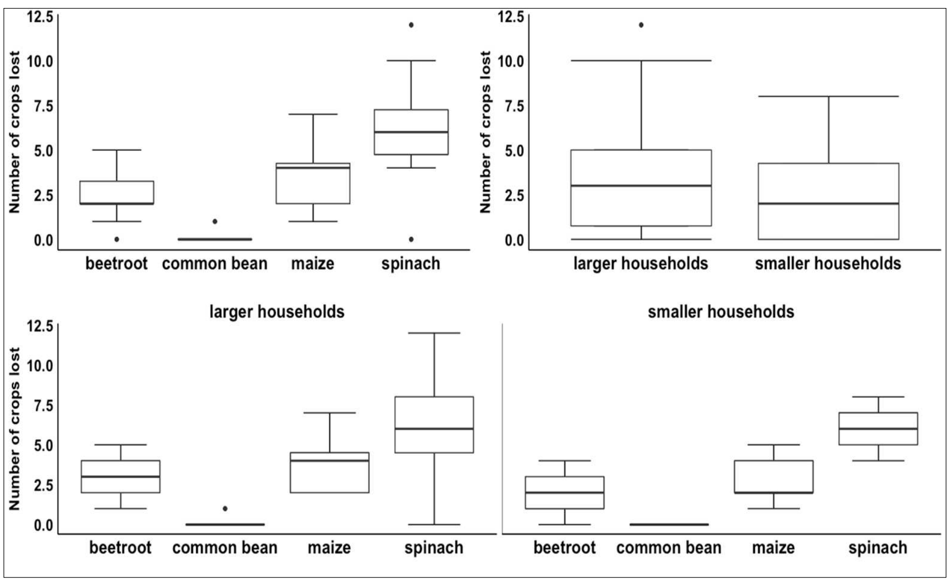

Figure 6.3. Number of crops lost by crop type (top left), homestead size (top right) and the interaction between crop type and homestead size (bottom) in subsistence farming homesteads on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and dots outside of boxes indicate outliers.

Relative calorie loss

Crop type (Wald χ^2_3 = 17987.70, P < 0.001), homestead size (Wald χ^2_1 = 157.90, P < 0.001) and crop contribution (Wald χ^2_1 = 43.70, P < 0.001) were significant predictors of the relative calorie loss. Significantly higher calorie losses: 1) occurred for maize followed by common bean, spinach and beetroot; 2) were recorded in larger homesteads compared to smaller homesteads and occurred when crops contributed 91%-100% to homestead food basket followed by 31%-60% and 61%-90% (Figure 6.4).

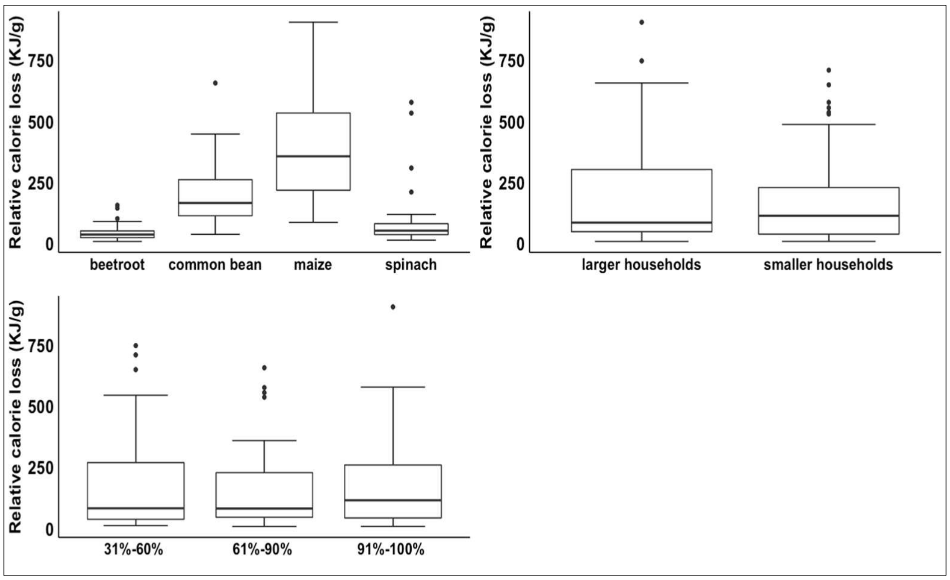

Figure 6.4. Relative calorie loss by crop type, homestead size and crop contribution experienced by farmers on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show confidence limits and dots outside of boxes indicate outliers.

The interactions between homestead size and crop type (Wald χ^2_3 = 628.50, P < 0.001), homestead size and crop contribution (Wald χ^2_1 = 67.10, P < 0.001), crop type and crop contribution (Waldχ^2_3 = 317.30, P < 0.001) and the three-way interaction between homestead size, crop type and crop contribution (Wald χ^2_3 = 217.30, P < 0.001) were significant predictors of the relative calorie loss. Significantly higher calorie losses were: 1) in larger homesteads for maize as compared to smaller homesteads for all crop types; 2) in larger homesteads with 91%-100% crop contribution to the homestead food basket as compared to smaller homesteads and for all crop contribution; 3) for maize with crop contributions of 91%-100% compared to all the other crop types and across all crop contribution; 4) in larger homesteads compared to smaller homesteads for maize with crops contribution of 91%-100% across all crop types and crop contribution (Figure 6.5). Farm size was also a significant predictor of the relative calorie loss (Wald χ^2_1 = 184.2, P < 0.001). However, a Spearman rank analysis showed a non-significant relationship between farm size and relative calorie loss (r_s = 0.01; p = 0.844; Figure 6.5).

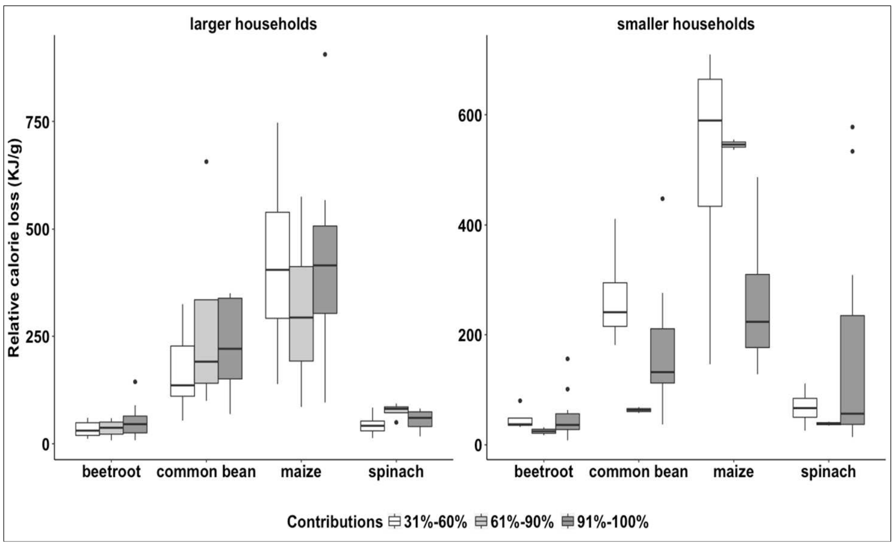

Figure 6.5. Relative calorie loss by homestead size*crop type*crop contribution (three way interaction) experienced by subsistence farmers on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers shows confidence limits and dots outside of boxes indicate outliers.

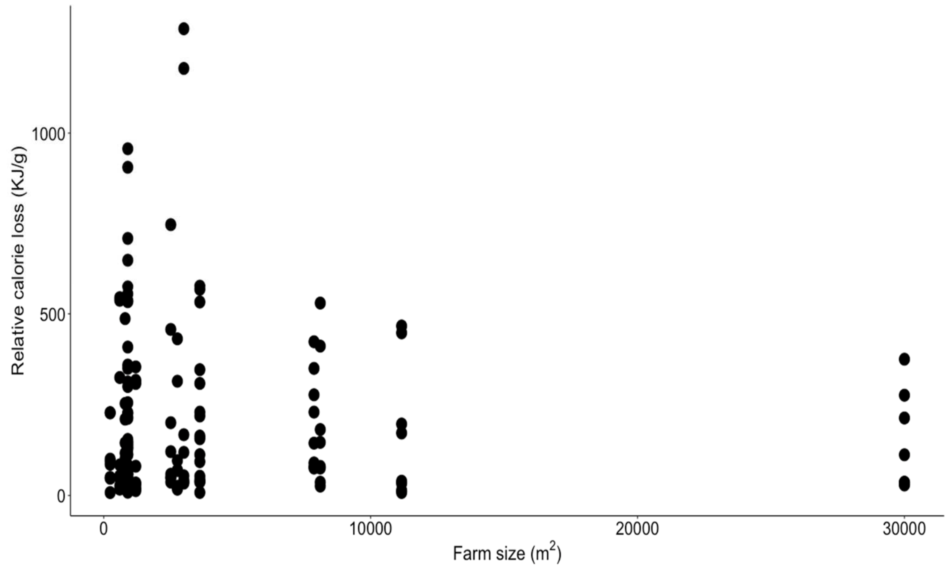

Figure 6.6. Scatterplot of the relationship between relative calorie loss and farm size for subsistence homesteads on the edge of Hluhluwe Game Reserve, South Africa.

Potential income loss by homesteads

Crop type (Wald χ^2_3 = 1192.02, P < 0.001), homestead size (Waldχ^2_1 = 9.47, P = 0.002) and the interaction between crop type and homestead size (Wald χ^2_3 = 90.25, P < 0.001) were significant predictors of the potential income loss. Significantly higher potential income loss was recorded for spinach followed by maize, beetroot and common bean, and larger homesteads suffered higher potential income loss compared to smaller homesteads. Moreover, significantly higher potential income loss occurred for spinach in larger homesteads compared to smaller homesteads (Figure 6.7). Farm size also affected the potential income loss (Wald χ^2_1= 18.63, P < 0.001). A Spearman rank analysis showed a significant negative relationship between farm size and the potential income loss (r_s=

-0.56, P = 0.007; Figure 6.8). The effect size of this relationship was weak (d = 0.4; Cohen, 1988). Squaring the correlation coefficients indicated that 31.36% of the variance in potential income loss was explained by the size of the farms.

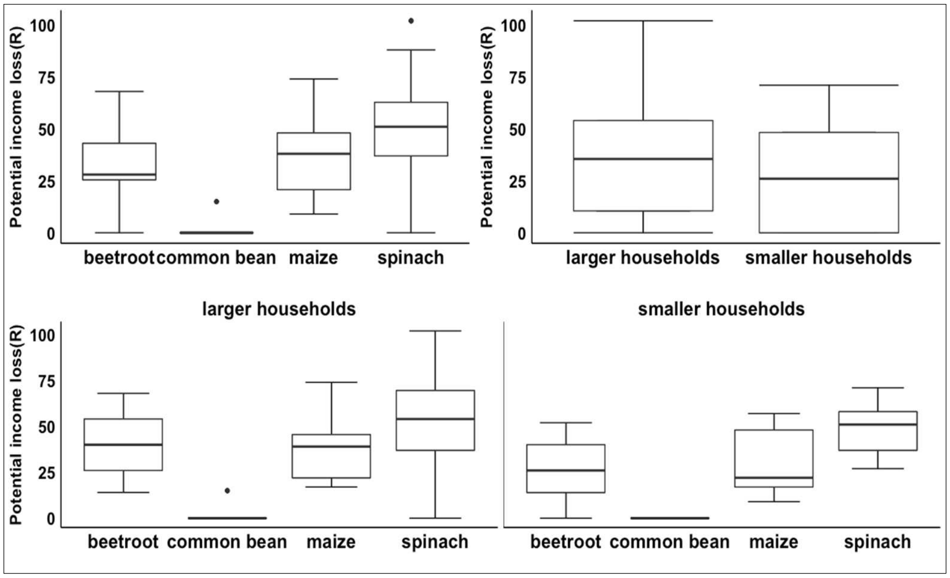

Figure 6.7. Potential income loss by crop type (top left), homestead size (top right) and the interaction between crop type and homestead size (bottom) experienced by farmers on the edge of Hluhluwe Game Reserve, South Africa. Boxes show medians (solid black line across the box) and 1st (top box) and 3rd (bottom box) quartiles. Whiskers show total range and dots outside of boxes indicate outliers.

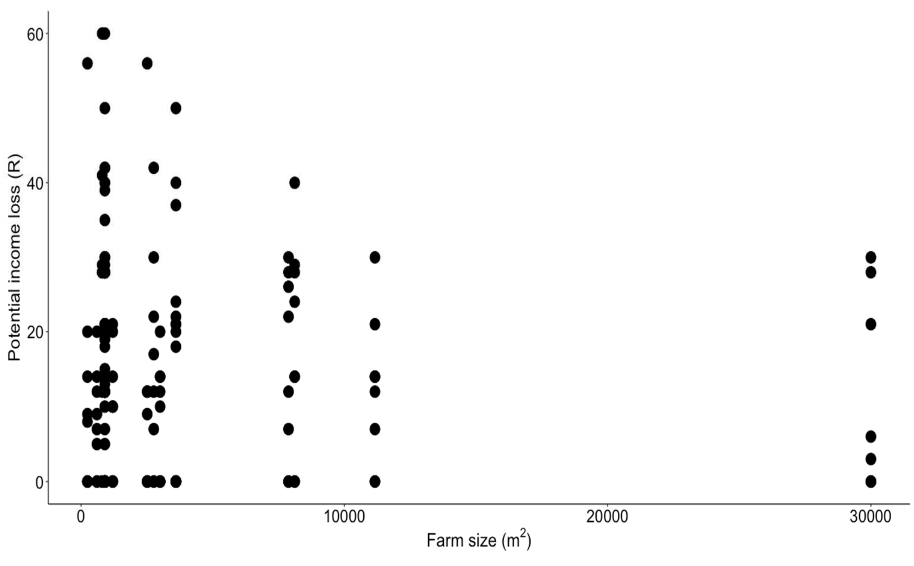

Figure 6.8. Scatterplot of the relationship between farm size and potential income loss for subsistence homesteads on the edge of Hluhluwe Game Reserve, South Africa.

Since farm size was a significant covariate predictor of income loss and also because homestead size predicted income loss, I also assessed the relationship between farm size and homestead size. There was a significant negative relationship between farm size and the homestead size (r_s = - 0.19, P = 0.015; Figure 6.9).

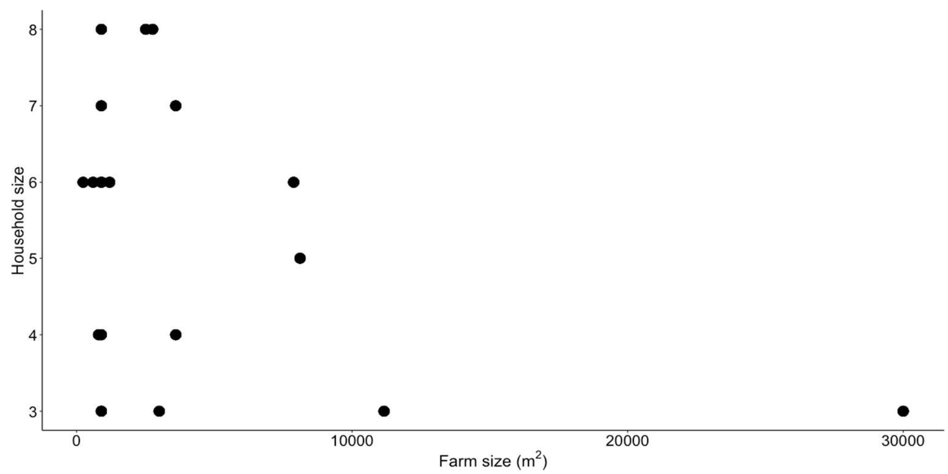

Figure 6.9. Scatterplot of the relationship between homestead size and farm size for subsistence homesteads on the edge of Hluhluwe Game Reserve, South Africa.

I ran another Spearman rank correlation without the 30 000 m^2 farm outlier (Figure 6.9), and found a non-significant negative relationship between farm size and the homestead size (r_s = -0.07, P = 0.328; Figure 6.10).

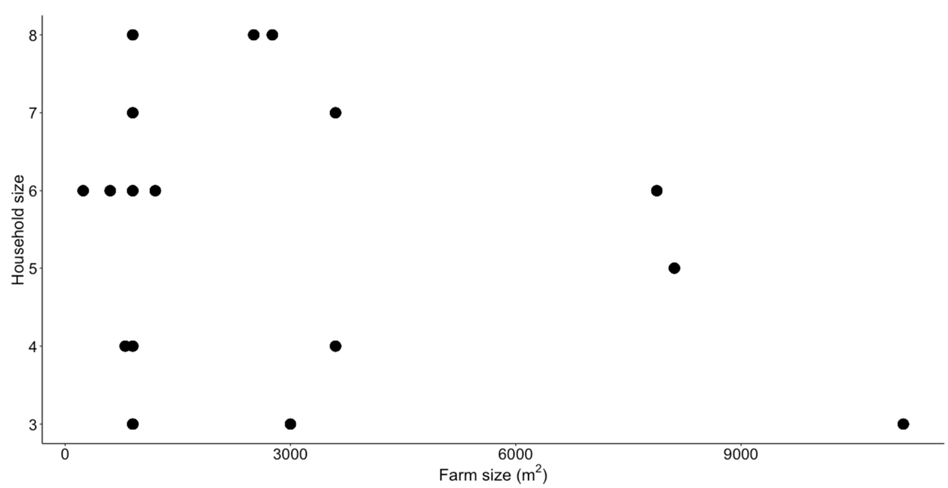

Figure 6.10. Scatterplot of the relationship between homestead size and farm size for subsistence homesteads on the edge of Hluhluwe Game Reserve, South Africa.

Discussion

Several factors can be linked to homestead food security of subsistence farmers (Altman, *et al*., 2009). Here I investigated how crop raiding by wildlife affects food security of subsistence homesteads adjacent to the Hluhluwe Game Reserve, South Africa. I found that the number of crops lost was positively related to income loss but there was no relationship between crop loss and calorie loss. Between farm assessments revealed that the highest number of crops, relative calorie and potential income losses occurred in larger homesteads as compared to smaller homesteads and in homesteads where food crops contributed 91%-100% to the homestead food basket. In particular, spinach was lost more than maize. This was not surprising since spinach is an annual crop and continues to grow and produce new leaves after damage (Hora *et al*., 2005), which makes it the most abundant crop in most subsistence homesteads as compared to maize which, when damaged, would have to be replanted (Sharp & Davies, 1979).

As a guideline for food security, Altman *et al*. (2009) maintained that people's diets must meet the requirements for a healthy life. I investigated the potential calories lost in crops raided. Larger homesteads experienced higher relative calorie loss compared to smaller homesteads, particularly for maize. Following the definition of food security by the FAO (2016), this finding implies that larger homesteads were more prone to food insecurity compared to smaller homesteads. In South Africa, as in many developing countries, maize is considered a food security food group (Altman *et al*., 2009). It provides at least 30% of the food calories for more than 4.5 billion people in 94 developing countries and also contributes to over 20% of food calories in parts of Africa and Asia (FAOSTAT, 2010). Thus, maize is also a key indicator in the assessment of food security in most developing countries since it is important to the poor as a means of overcoming hunger (Shiferaw *et al*., 2011). In North-eastern Tanzania, crop raiding by wildlife, such as chacma baboon (*Papio ursinus*), buffalo (*Syncerus caffer*), vervet monkey (C*hlorocebus pygerythrus*), zebra (*Equus burchellii*), hippopotamus (*Hippopotamus amphibious*), elephant (*Loxodonta africana*) and wild pig (*Sus scrofa*), reduced maize yields that could sustain a family to only 11 months per year (Kaswamila *et al*., 2007). Moreover, I found that the highest relative calorie loss occurred in homesteads where maize contributed the highest (91%-100%) to the food basket, implying that these homesteads were more prone to food insecurity. I also found that farm size and crops lost did not predict calorie loss. However, the relationship between the number of crops lost and the number of calories lost was not significant, indicating that potential calorie loss is uncoupled from crop loss in my study or that the measurement of calorie loss (Chapter 3) was not sensitive enough to detect energy loss in terms of the numbers of crops lost.

Larger homesteads suffered higher potential income loss compared to smaller homesteads. This loss was the highest for spinach compared to all the other crops damaged. Income loss amounted to R2 427 (about US$180.71) per homestead per annum. Larger homesteads incurred R1 469 (about US$109.38) per annum as compared to smaller homesteads, which incurred annual loss of R958 about (US$71.33). Assuming that all or most of the potential income lost was used to purchase food, this study suggests that for some periods, larger homesteads could be faced with food shortages. Indeed, Mkanda (1994) reported that around Kasungu National Park, Malawi, the extra income from selling cultivated crops provided the needed cash injection to reduce insecurity in the homesteads surrounding the Park.

I found a negative correlation between farm size and potential income loss, with smaller farms experiencing greater potential income loss compared to larger farms. The size of the farm can have an influence on the potential income loss, since the number of surplus food crops sold for income will depend on the number of crops damaged in the particular farm. Thus, smaller farms are prone to greater absolute loss than larger farms. Yet, farm size did not correlate with homestead size in my study, indicating that the relationship between income size, homestead size and farm size is not predictable. A literature search did not reveal any studies that considered the relationship between potential income loss and farm size, so the reason for this effect found by this study is unknown and requires further testing.

Furthermore, I found a negative correlation between homestead size and farm size which homestead size with small farms consisting of more people than small farms. Larger homesteads experienced the highest number of crops loss, suggesting that farm size contribute significantly to the vulnerability of these homesteads to food insecurity. Moreover, I found a positive correlation between potential income loss and the number of crops lost with higher income loss recorded in farms that lost more crops as expected, making this homesteads vulnerable to food security.

In conclusion, despite the small number of farmers studied, my findings suggest that crop raiding by wildlife potentially impacts subsistence homestead food security through loss of crops, calories and potential income. I found a positive relationship between the number of crops lost and income loss, suggesting that with an increase in the number of crops lost, homesteads could become impoverished leading to food insecurity. However, crops lost did not predict calorie loss and more studies with a larger number of farmers are needed to assess this relationship. Larger homesteads were more affected than smaller homesteads. Altman *et al*. (2009) reported that larger homesteads suffered most food insecurity amongst South Africa's rural poor. Moreover Aliber (2009) showed that a key determinant of homesteads whose situation diminished from being food secure in 2006 to being food insecure in 2007 included homestead size. My results also suggest that larger homesteads, and homesteads that contribute more maize crops to the homestead food basket are more prone to food insecurity in this rural subsistence farming homesteads.

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Concluding Remarks

Crop raiding is a common form of human-wildlife conflict, which directly affects poor, marginalised; rural subsistence farming communities abutting protected areas (Hill, 2000; Naughton-Treves, 1997; Treves *et al*., 2006). There is evidence that crop raiding by mammals is a serious issue affecting subsistence farmers in Africa, but few in-depth studies have investigated this issue holistically, especially in South Africa (Infield 1986; Seoraj-Pillai, 2016). I investigated crop raiding by wildlife on subsistence farmers adjacent to the Hluhluwe Game Reserve in KwaZulu-Natal Province, South Africa. My specific objectives were to investigate how these farmers were affected by crop raiding and how crop raiding was perceived by both farmers and conservationists employed by the reserve.

I used several techniques in my study. I employed field sampling of different wildlife, especially rodents and primates, using live trapping and deployment of remote camera traps. Laboratory techniques (i.e. bomb calorimetry) were used to analyse the potential energy loss due to crop raiding. I used semi-structured questionnaire interviews of stakeholders. Finally, I investigated the effects of crop raiding on homestead food security of the subsistence farmers, using the accumulated data set. My research, which was a case study in a single community, revealed that crop raiding by wildlife potentially impacted the livelihood and lives of subsistence farmers. Whether or not this influences their food security was not fully demonstrated in my study.

Crop raiding

In my study, farmers' reports of high prevalence of crop raiding by small animals matched my field observations. This was also contrary to my prediction that the vervet monkey (*Chlorocebus pygerythrus*) is the leading crop raider. Instead, surprisingly, primates did not leave the reserve to raid farms, which I suggest may be due to the fact that the reserve fence was being refurbished during the study and there were always people inside and outside the reserve boundaries, potentially disrupting the behaviour of primates. Primate crop-raiding behaviour has been studied previously in Africa and many of these studies reported primates as formidable crop raiders (Campbell *et al*., 2010; Linkie *et al*., 2007; Tweheyo *et al*., 2005).

Hluhluwe Game Reserve management maintain their boundaries by refencing of the reserve barriers (personal observation). Maintained protected area boundaries could be an effective deterrent for crop raiding (Nyhus, 2010). Therefore, the protection by the Hluhluwe Game Reserve and control measures employed by farmers in my study, mainly patrolling, could have produced the unusual findings in my study. Moreover, the occurrence of drought during my study could have impacted the population numbers of large herbivores in the reserve. However, reasons for their lack of attempts to transgress the park boundary to access the agricultural crops are unknown. Herbivores are known the world over to be a nuisance when it comes to crop raiding, especially larger herbivores, which can overcome modifications to fences, regardless of the design, construction and voltage of electric fences to access food and water during challenging environmental conditions (Thouless & Sakwa, 1995). Osborn & Hill (2005) further reported that an expensive 'arms race' could develop between managers of protected areas and elephants that are able to adapt quickly to new fence features designed to electrify the parts of the fence that elephants destroy. Other species (e.g. mountain nyala *Tragelaphus buxtoni*; Mamo, 2015) can exploit the breaks in the fences made by elephants to raid crops.

The impact of crop raiding by larger mammals can be devasting to local communities compared to that of small mammals. For example, elephants inflicted catastrophic damage to farms around Kibale National Park in Uganda, and the distribution of damage was highly skewed to maize (*Zea mays*) and cassava (*Manihot esculenta*) fields, which were sometimes completely destroyed (Naughton-Treves, 1998). In the Congo, near Okapi Wildlife Reserve, Pilipili *et al*. (2018) reported that bush pig (*Potamochoerus larvatus*) caused the highest scale of damage compared to free-living birds. Spagnoletti *et al*. (2017) reported that primates consumed between 73 and 100 % of the crops whereas small animals consumed between 15 and 23% of crops in a rural subsistence community in Brazil.

Nonetheless, many studies reported small animals amongst the major problems in agricultural land (Hill, 2000; Gillingham & Phyllis, 1999; Naughton-Treves, 1997; Treves *et al*., 2006). Unlike large mammals, small animal impacts are often continuous, resulting in sustained damage (Jacob *et al*., 2003). In support, Singleton *et al*. (2005) reported that regular and on-going rodent damage to rice crops in Asia amounted to 36 million tons (i.e.

enough to feed the population of Indonesia for 12 months). In Uganda, Hill (1997) found that small animals caused widespread damage to maize.

I trapped two rodent species, *Saccostomus campetris* and *Aethomys* sp., in my study and their numbers were low; trapping success throughout my study was 0.03% per trap night. In addition, the diverse assemblage of rodents present at Hluhluwe Game Reserve was not reflected in my study. Hagenah *et al*. (2009) reported the single striped mouse (*Lemniscomys rosalia*) as the most abundant rodent inside the reserve. In addition, Hagenah *et al*. (2009) trapped the multimammate mouse (*Mastomys natalensis*), but in low numbers. The multimammate mouse is a formidable crop raider, causing an estimated 5–15% loss of maize in Tanzania (Leirs, 2003) and 30-100% crop loss in other parts of Africa (John, 2014; Singleton *et al*., 2010). The low rodent numbers and diversity might be a consequence of the prevailing drought during my study. Many studies have associated rodent abundance with higher rainfall; rodent species often fluctuate dramatically in abundance, being absent or in low numbers during the droughts but erupting after significant rainfall (Dickman *et al*., 1999; Mills *et al*., 1999; Ostfeld *et al*., 2000).

Insects were the most reported crop raiders by farmers. Several studies have reported that most protected areas around the world do not keep records of smaller animals because of their cryptic nature (Thiollay, 2006). Yet, their importance in conservation and biodiversity has been widely documented (Angold *et al*., 2006), and their importance as crop raiders is widely known. Much has been written about insect damage to standing crops (Hill, 1999). In Indonesia, near Kerinci Seblat National Park in Sumatra, crop damage by insects contributed to be 66% of total damage by wildlife (Linkie *et al*., 2007). The farmers employed lethal control measures to prevent damage of their crops by insects, such as the insecticide Malasol (containing the organo-phosphate malathion) to control crop-raiding insects (personal observation), which might have also reduced the impact of insect pests.

The impact of crop raiding

Although I found matching information in the reports of crop raiding animals from farmers and my own observations, there was no evidence that crop raiding was a major issue in the community. Even the levels of damage were not as high as reported in other studies, where entire crops could be decimated (Gillingham *et al*., 2003). Yet I found some evidence that crop raiding by small animals leads to potential energy and income loss for subsistence homesteads studied and the impact of crop raiding was greater during the dry season. My study also revealed an overall potential income loss of R2 427.00 (about US$ 180.71) per annum across all farms studied. This suggests that subsistence farmers might be particularly impacted by food insecurity during the dry season, a pattern reported elsewhere (Bukie *et al*., 2018; Fungo *et al*., 2013; Hill, 1997; Patterson *et al*., 2017; Sillero-Zubiri & Switzer, 2001; Wilkie & Douglas-Hamilton, 2018). During the dry season, natural food for wildlife is scarce, often leading to their crop raiding (Chiyo *et al*., 2005; Sukumar, 1990).

Crop raiding negatively impacts the lives and livelihoods of subsistence farmers (Hill *et al*., 2002; Hill & Wallace, 2012) by causing poor nutrition and income loss (Barirega *et al*., 2010; Chiyo, *et al*., 2012). General environmental conditions prevalent in South Africa, such as low rainfall and drought (in my study), could exacerbate the impact of crop raiding (Thorn *et al*., 2012). Importantly, these findings are of a particular concern because the subsistence farmers studied represents some of the poorest homesteads in South Africa (StatsSA, 2011). Thus, my results suggest that crop-depredation could potentially compromise homestead food production and nutrition.

Several studies have reported significant potential income losses for subsistence crops due to wildlife depredation (Butler, 2000; Holmern & Roskaft, 2013; Osborn & Parker, 2003). However, the potential income losses incurred by subsistence farmers worldwide are still debatable (Barbehen *et al*., 2004). Some studies (Mturi, 1991; Saj *et al*., 1998; Sillero-Zubiri & Switzer, 2001) demonstrated that crop damage could potentially affect subsistence farmers' livelihoods whereas others showed negligible losses to subsistence farmers when compared with the losses to commercial farmers (Mkanda, 1994; Nahonyo, 2001; Naughton- Treves, 1998). Nevertheless, Kates & Dasgupta (2007) reported that these losses translate into other impacts for subsistence farmers' livelihoods. The money lost due to crop damage could be used to purchase other food products to supplement their diets (Kates & Dasgupta, 2007). Hence, crop loss due to damage could have a nutritional cost as well as economic loss, even though the income lost is often insignificant compared to international values.

Human-wildlife conflict studies have reported crop raiding as an issue that undermines homestead food security (Hill, 2000; Infield *et al*., 2001). I found higher number of crops lost in larger homesteads, suggesting that these were more prone to food insecurity as compared to smaller homesteads. In particular larger homesteads, particularly where maize (*Zea mays*) contributed substantially (91%-100%) to homestead food baskets, were more prone to food insecurity. Maize is a food security crop in South Africa (Altman *et al.*, 2009), Maize contributes at least 30% of the food calories to more than 4.5 billion people in 94 developing countries, and also contributes to over 20% of food calories in parts of Africa and Asia (FAOSTAT, 2010).

Based on a positive correlation between potential income loss and the number of crops lost, my study suggests that crop raiding by wildlife has the potential to impact subsistence homestead food security through loss of crops, calories and potential income. However, whether the studied community was food insecure could not be accurately documented in my study. Indeed, rural farmers often seek help from neighbours, and the South African government also intervenes in situations where homesteads are food insecure, by registering the homesteads as indigent and providing food parcels given monthly to such homesteads (Altman *et al.*, 2009). The Hluhluwe Game Reserve can also assist by providing employment to the affected farmers, which might also serve to mitigate concomitant poaching (Nyhus *et al.*, 2005).

Conclusions

I investigated the impact of crop raiding by wildlife, especially rodents and primates, on subsistence farmers on the edge of the Hluhluwe Game Reserve. My study was the first to consider human-wildlife conflict in marginalised rural communities by directly measuring the impact of wildlife and by soliciting the views and opinions of subsistence farmers. I hypothesised that crop raiding by wildlife would impact the livelihood and lives of subsistence farmers and compromise their food security. I found evidence of crop raiding by wildlife. Specifically, I found that rodents and insect frequently depredated staple food security crops (maize) and other crops, including the common bean, beetroot and spinach. Moreover, I found that larger homesteads and small farms were more prone to food insecurity. However, the crop raiding animals and the level of damage recorded would have been unlikely to cause food insecurity in the studied homesteads. Thus, my study indicates potential but not actual food insecurity because of crop raiding.

I found several variables that determined how human-wildlife conflict can be exacerbated by crop raiding behaviour of wildlife. Seasonal variations influenced crop-raiding behaviour in my study, and therefore crop raiding mitigations measures by both farmers and the reserve management should be intensified during the dry season. The most prominent crop raiders found in my study were small mammals, so exclusive fencing maybe a long-term solution. However, subsistence farmers do not have the resources for such determents. Instead, they employ other, often passive, forms of wildlife control. Therefore, the loss of food crops, in particular maize crops, due to crop raiding will exacerbate their plight, leading to food insecurity.

Future studies

My study suggests several areas of future research. 1. There is a need for a long-term study of the Phindisweni community to cover many seasons over several years. This will provide an important comparison for the data obtained in my study, which was conducted during a drought. 2. Other proxies of loss of crop raiding, such as crop yield, need to be considered. Although I attempted to quantify economic and nutritional loss of crop parts through the damage, crop yield prior to and after damage was not known because farmers did not keep crop yield information (e.g. pre-and post-harvest) during the prevailing drought. Studies around Africa and India have investigated loss based on crop yield (Mackenzie & Ahabyona, 2012; Sekhar, 1998). In India, near Tiger Reserve, Sekhar (1998) found that the crop yield was approximately 30-35% more than when there was no major damage. Around the Kibale National Park in Uganda, Mackenzie & Ahabyona (2012) reported 20% loss of crops due to crop raiding compared to the crop yield without damage in the previous six months. 3. Future investigations should incorporate more detailed nutritional analyses of cultivated foods consumed at different times of the year, and patterns and changes over longer periods of time. Sampling might have to be done opportunistically since crop raiding can be unpredictable, depending on a particular set of environmental conditions (e.g. high rainfall, high crop yields and ease of accessibility of wildlife to crops). 4. I suggest that prospective studies incorporate a mixture of analytical methods to quantify food security, such as including questionnaire interviews that ask farmers about the food they consumed to quantify food security using dietary diversity. Such methods would be critical in evaluating how food crops contribute to the homestead food basket (Hill, 2000). 5. Although my study has shown that crop raiding is a challenge for the farmers, I do not have data about how they can mitigate against food insecurity should this arise. 6. Finally, we also need studies in other parts of South Africa, especially where subsistence farmers abut protected areas with different environmental conditions to assess whether or not my findings are generalisable across South Africa.

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