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Human-wildlife conflict in subsistence and commercial farmers in north-eastern South Africa

Nimmi Seoraj-Pillai

A thesis submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy

Johannesburg 2016

DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the Degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.



Nimmi Seoraj-Pillai

5th day of September 2016

ABSTRACT

Human-wildlife conflict (HWC) occurs when wild animals depredate crops and livestock and threaten human safety, which subsequently results in retaliatory or deliberate persecution of wildlife by farmers. The aim of my study was to establish how subsistence and commercial farmers that ranched or cultivated in the same geographic area were affected by and responded to problem animals in selected localities of north-eastern South Africa. I first conducted a global meta-analysis of the scientific literature concerning HWC, which revealed several findings. 1) Local communities contiguous with protected areas worldwide were affected by the highest number of damage-causing wildlife (49 species) compared with subsistence farmers and commercial farmers. 2) Contrary to my prediction, subsistence farmers did not experience the highest number of depredation incidences, instead, commercial farmers were more prone to HWC, possibly due to a greater research focus on commercial agri-pastoral farming. 3) Consistent with the prediction that developing countries could potentially experience regular encounters with wildlife, rural people in Africa and Asia experienced conflict with the broadest diversity of mammals. 4) South Africa offers a regional exemplar of global patterns in HWC.

Subsequently, I investigated how subsistence and commercial farmers that operated concurrently in selected localities of north-eastern South Africa were affected by and managed damage-causing wildlife. In addition, I gauged the attitudes and opinions of subsistence and commercial farmers to wildlife and conservation issues, and assessed the attitudes and opinions of conservation practitioners towards people living on protected area boundaries. Finally, I investigated the movement patterns of African wild dog (wild dog) *Lycaon pictus* in areas where they are lethally persecuted, as a case study of HWC. To achieve these aims, I employed a combination of methods and approaches to acquire information regarding the demographic and physical attributes (such as fencing and use of irrigation) of subsistence and commercial farms, in addition to respondent attitudes and opinions that were collectively important predictors of the scale of HWC. These included semi-structured questionnaire interviews, site inspections on farms and subsistence gardens to verify farm attributes, geographic information system attitude indexes (methods to visualise the spatial distribution of respondent attitudes) and satellite or radio-collared wild dog individuals.

Several variables, such as large households (≥ seven occupants per household) and environmental-related challenges (e.g. insect pests, soil erosion, and the absence of electrified

fencing) exacerbated HWC, especially regarding carnivores. Maize *Zea mays*, was the most frequently raided crop (by primates) on both subsistence and commercial farms. Poultry and young livestock were most often depredated throughout the study sites, with caracal *Caracal caracal*, wild dog and leopard *Panthera pardus* being the main depredators. My findings supported the prediction that commercial farmers more readily shot and poisoned wildlife compared to subsistence farmers. Commercial farmers most frequently persecuted carnivores, while subsistence farmers mainly persecuted primates. Subsistence and commercial farmers held positive and negative attitudes towards wildlife for different reasons. Collectively, positive attitudes related to ecocentric values (concern for the ecosystem) such as environmental education, tourism and a willingness to learn about non-harmful damage-causing animal control, while negative attitudes pertained to stray wildlife and resource damage, specifically to crop and livestock depredation. Although conservation practitioners held positive attitudes of local human communities (relating to community-conservation oriented values), negative attitudes also existed (pertaining to a disinterest and indifference towards the socio-economic needs of local human communities and poaching). My study of wild dogs showed that although the home range of free-ranging packs intersected with lethal-controlling commercial farmers, one pack in the Waterberg, Limpopo Province, reduced potential encounters with farmers by utilising vegetation thickets as refugia.

I concluded that subsistence farmers and commercial farmers were similarly affected by HWC but differed in the type of farming commodity depredated. While commercial farmers may be able to discourage depredation by using fencing and lethal control, such resources are unaffordable or unavailable to subsistence farmers. Instead, they utilised passive methods to deter wildlife (e.g. chasing, guarding fields). The loss of household food to depredation coupled with adverse environmental factors may compromise the food security of poor households. Although tensions between local human communities and conservation authorities exist, the positive attitudes and opinions of subsistence and commercial farmers towards biodiversity, as well as the reported alacrity of conservation authorities for community conservation, may provide the basis for future discussions on joint wildlife management. In the absence of such collaborations, wildlife will continue to experience conflict in farmed areas, or they might adapt by modifying their behaviour, as demonstrated in one wild dog pack.

DEDICATION

In loving memory of my mother

Anganee Seoraj

1946 – 2011

(who, despite poverty and destitution, raised me up to stand on mountains)

"Civilised man has gone deaf.
He can't hear the wolf calling him brother- not Master,
but brother.
He can't hear the earth calling him child- not father,
but son.
He hears only his own words making up the world…
This is the myth of Civilisation,
embodied in the monotheisms which assign soul to Man alone."

Ursula K. Le Guin

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LIST OF ABBREVIATIONS

APNR	adjoining protected nature reserves
CBNRM	community-based-natural-resource management
CCP	Carnivore Conservation Programme
CE	community engagement
DCA	damage-causing animal
EE	environmental education
EWT	Endangered Wildlife Trust
FR	future research
GDP	gross domestic product
GIS	geographic information system
GLMM	generalised linear mixed model
GPS	global positioning system
GPS-UHF	global positioning system-ultra high frequency
HREC	Human Research (Non-Medical) Ethics Committee
HSC	high-scale conflict
HWC	human-wildlife conflict
IUCN	International Union for Conservation of Nature
KDE	kernel density estimation
KNP	Kruger National Park
LSC	low-scale conflict
MCP	minimum convex polygon
MP	medium or moderately persecuted
MSC	moderate-scale conflict
PA	protected area
PR	poorly researched
QGIS	Quantum Geographic Information System
RR	research required
SANParks	South African National Parks

SIM	subscriber identity module
SP	severely persecuted
SU	status unknown
TUT	Tshwane University of Technology
UHF	ultra-high frequency
USA	United States of America
WITS	University of the Witwatersrand

CHAPTER ONE

General introduction

An overview of human-wildlife conflict

The earliest occurrences of human-wildlife conflict (HWC) can be traced back to the Neolithic period (Anderson, 1997; Treves et al., 2006), coinciding with the development of grain cultivation and the domestication of animals (Zeder, 2008). With agricultural expansion came human population growth and the earliest ecological impacts of farming (e.g. deforestation and soil erosion) that can be dated back to 9000 BC (Colledge, 2004; Zeder, 2008). Archaeological and paleo-ecological evidence also indicate that direct human alteration of terrestrial ecosystems occurred with hunting of wild animals, foraging on wild flora and transforming indigenous landscapes for agri-pastoral farming (Colledge, 2004), eliciting conflict with wildlife.

I refer to HWC as any instance in which the resource demands of humans and wild animals overlap, spurring competition for food, space and water and the ensuing tension between people and wildlife authorities (Gilbert and Dodds, 2001; Woodroffe et al., 2005). Human-wildlife conflict often follows when wild animals damage crops, poultry, livestock, farmed game and fisheries and jeopardise human safety (Peterson et al., 2010), frequently resulting in retaliatory or deliberate persecution of conservation priority species by people outside and within the boundaries of protected areas (PAs) (Graham et al., 2005; Thorn et al., 2012). I refer to a protected area as a biodiversity conservation area that receives protection due to the presence of indigenous wild fauna and flora that have ecological value (Chape et al., 2005).

As natural habitats become increasingly fragmented and transformed into agricultural farmland to accommodate the expanding human population (Thornton et al., 2011), wild animals often depredate crops and livestock, especially in rural areas (Hill, 2000). These wildlife depredations can pose serious threats to people and food security and cause adverse impacts on the local economy at the household level (Treves et al., 2006). Simultaneously, wild animal populations are declining dramatically due to habitat degradation as well as poaching, exploitation and lethal control (Hazzah et al., 2009; Treves et al., 2006; Woodroffe et al., 2004). In many cases, seeing no value in wildlife and considering it vermin, deliberate "revenge killings" of charismatic mega-fauna (large-bodied mammals) become common (DeGeorges and Reilly, 2009; Treves et al., 2006). These problems warrant serious

consideration by concerned parties, including mediatory action by conservation authorities, government, biologists and non-governmental organisations to minimise food insecurity due to wildlife depredations and conserve species that are threatened by anthropogenic impacts.

Anthropogenic impacts on wildlife

Today, the pressure to house and feed a rapidly growing human population is the leading cause of encroachment onto pristine indigenous habitats (Siex and Struhsaker, 1999). As a result, indigenous fauna and flora have been reduced substantially or displaced from their natural geographic ranges (Woodroffe et al., 2005). Loss of indigenous habitat is a global conservation issue that affects ecosystem integrity in several ways (Kideghesho et al., 2006; Naughton-Treves, 1999). For example, the over-collection of fuel wood has led to the conversion of wooded vegetation to open grasslands, thereby reducing or extirpating populations of many browse-dependent animals (Kideghesho et al., 2006; Naughton-Treves, 1999). Roan antelope *Hippotragus equinus* have disappeared from the Serengeti due to loss of woody species of *Combretum* (Kideghesho et al., 2006). Yellow-casqued hornbills *Ceratogymna elata* have been extirpated from riverine forests due to loss of tree cover (Kideghesho et al., 2006). Other human impacts have reduced the blue wildebeest *Connochaetes taurinus* population in the Maasai-Mara by 75% due to transformation of critical breeding and calving grounds into wheat *Triticum* spp. fields (Dublin, 1995; Kideghesho et al., 2006). Similar losses of insectivorous and granivorous bird diversity due to a reduction in insect abundance through cultivation have been documented (Kideghesho et al., 2006).

Several noteworthy impediments challenge HWC mitigation. These include the rapid increase in the human population, which is predicted to reach 9.2 billion people by 2050 (Thornton et al., 2011; UNDP, 2008), and pressure on food production systems to transform indigenous biomes into farmland and habitat destruction, such as deforestation and fuel wood harvesting (DeGeorges and Reilly, 2009; Ehrlich, 1995; Harvey et al., 2008). In Africa, food production systems must be able to sustain an additional one billion people in the next 35 years (Thornton et al., 2011). The corresponding demand for livestock and crop production will therefore be particularly significant for countries in Sub-Saharan Africa (DeGeorges and Reilly, 2009). In addition, it is anticipated that in the next 15 to 20 years, crop and meat production must increase by 43% and 124% respectively to meet the rapidly growing global human population (FAO, 2009).

Growth in dairy, red meat, egg and poultry production reflects the rapid intensification of food production systems worldwide (FAO, 2015). According to the Food and Agricultural Organization (FAO) (2015), populations of commercial cattle *Taurus* spp. and water buffalo *Bubalus bubalis* will reach a total projected population of 2 032 million individuals by 2050 (from a joint population of 1 045 million individuals in 1970) for worldwide meat production for global human consumption. In addition, sheep *Ovis aries* and goat *Capra* spp. are expected to reach a total herd size of 2 930 million individuals (from a total population of 1 350 million individuals in 1970) in the next 35 years (FAO, 2015) to provide for global human food consumption. The global commercial poultry population will increase from about 4 400 million individuals in 1970 to ~37 billion during the same time to meet global human food consumption (FAO, 2015). It is expected that the repercussions of poultry and livestock population growth will likely lead to over-grazing and even desertification of grassland biomes in Sub-Saharan Africa (DeGeorges and Reilly, 2008; Millennium Ecosystem Assessment, 2005).

According to Hiernaux (2000), the impact of cultivation of crops on soils and wild flora is greater than that of livestock production. Expansion of cropland not only fragments indigenous landscapes (Hiernaux, 2000) but also extends to natural habitat degradation (Niamir-Fuller, 1999). For example, the conversion of savannah biomes to cropland in parts of the Serengeti-Mara ecosystem in East Africa, elicited a 60% decrease in resident wildlife populations (Serneels and Lambin, 2001). In South Africa, the cultivation of maize *Zea mays*, sorghum *Sorghum bicolor*, sugar cane *Saccharum* spp., wheat *Triticum* sp. and sunflower *Helianthus* sp. has been identified as a dominant contributor to the degradation of grasslands, accounting for about 23% of irreversible grassland biome transformation (Fairbanks et al., 2000).

Therefore, the sum of indigenous habitat encroachment, fragmentation and transformation has elicited high levels of resource depletion, forcing wild animals closer to human settlements and farms and increasing the possibility of them feeding on crops and livestock. Thus, the escalating human population has prompted a cascade of events (e.g. clearing of savannahs for crop production lead to biome transformation, and eventually indigenous habitat degradation, in addition to bringing humans closer to wild animals; Serneels and Lambin, 2001) that is intensifying HWC.

Impacts of human-wildlife conflict on biodiversity

Several issues have arisen because of conflict between humans and wildlife that serve to threaten wildlife populations (Gittleman et al., 2001, Naughton-Treves, 1999). Human-wildlife conflict has resulted in poaching of wildlife for bush meat (DeGeorges and Reilly, 2008), ivory and pelts (Gittleman et al., 2001; Naughton-Treves, 1999) and the retaliatory shooting, snaring, spearing and indiscriminate poisoning of wild animals (Ogada et al., 2003; Studsrod and Wegge, 1995). Numerous retaliatory and deliberate control methods have emerged, for example, the deliberate modification of power lines by farmers to electrocute the crop-raiding Asian elephant *Elephas maximus* or the indiscriminate packing of explosives in jackfruit *Artocarpus heterophyllus* as bait for a variety of crop-raiders in India (Woodroffe et al., 2005). In the United States, protective livestock collars that are equipped with 'Compound 1080' which constitute pouches of sodium fluoroacetate are circulating illegally as a predacide (Woodroffe et al., 2005). These collars are engineered to release poison when a predator attacks collared livestock with a throat bite (Woodroffe et al., 2005). Exposure to the poison results in a slow death that can take up to 15 hours (Woodroffe et al., 2005). Despite the banning of Compound 1080 in 1972, not every stockpile was recalled; this toxin is reportedly being used currently to control wolf *Canis lupus* and coyote *Canis latrans* populations (Woodroffe et al., 2005).

The impacts of lethal control extend far beyond population numbers and bear ramifications for the population density, reproduction and genetic variability of the conflict species (Gittleman et al., 2001; Woodroffe et al., 2005). Persecution of conflict species has led to extirpations, as in the case of the gray wolf *Canis lupus* (throughout North America), and geographic range shrinkages, as in the case of the prairie dog *Cynomys ludovicianus* (North America) and the cheetah *Acinonyx jubatus* (Asia and parts of Africa) (Gittleman et al., 2001; Woodroffe et al., 2005). Control of problem animals has also led to population declines in the African lion (throughout Asia and parts of Africa) *Panthera leo*, grizzly bear *Ursus arctos horribilis* (western North America) and hen harrier *Circus cyaneus* (throughout Britain) and extinction of other species such as the Tasmanian tiger *Thylacinus cynocephalus* (Australia) (Gittleman et al., 2001; Woodroffe et al., 2005).

Secondary effects of lethal control may include disruptions in animal social behaviour. For example, the retributive killing and deliberate persecution of male conspecifics in a chimpanzee *Pan trogodytes* troop by humans reportedly affected the group's ability to ward off predation (Gittleman et al., 2001; Woodroffe et al., 2005). Similarly, when African wild

dogs *Lycaon pictus* were killed in retaliation, the removal of even a few individuals affected the pack's hunting and breeding success (Courchamp and Macdonald, 2001). Other impacts may sometimes extend to trophic levels and even entire ecosystems (Gittleman et al., 2001; Woodroffe et al., 2005), especially when keystone species such as the African elephant *Loxodonta africana* are targeted (Dublin, 1995).

Control of damage-causing animals in South Africa

Historically, damage-causing animals (DCAs) in South Africa were exterminated by the indiscriminate use of poison, traps and snares rather than being managed using humane methods (Stadler, 2006). The lethal control methods were employed by large-scale colonial farmers, and episodes of conflict between colonial settlers and wild animals in South Africa can be dated as early as 1652 (Fabricius et al., 2004; Stadler, 2006). During the 17th century in South Africa, the government operated under the 'Ordinance on the Eradication of Vermin' (Stadler, 2006). Vermin not only included mammalian predators but also the Cape porcupine *Hystrix africaeaustralis* and the common mole-rat *Cryptomys hottentotus* that raided gardens of early Cape settlers (Stadler, 2006). Rewards or bounties were offered for the destruction of so-called 'noxious' species (Hey, 1974) due to pressure from the agricultural sector (Fabricius et al., 2004; Stadler, 2006). Under this bounty system, many blameless species such as the bat-eared fox *Otocyon megalotis* and the aardwolf *Proteles cristatus* were also targeted (Stadler, 2006). In 1953, the Ordinance became known as 'Problem Animal Control' (Stadler, 2006). Hence, the indiscriminate killing of wild animals, especially predators, continued unregulated for three centuries. For example, the African lion population, estimated to be half a million in 1950 had declined to 30 000 in 2006, translating into a 94% drop in the lion population with an 83% reduction in their geographic range size (IUCN, 2012). According to Stadler (2006), since 1975, about 20 000 black-backed jackal *Canis mesomelas* have been killed in the former Cape Province and since the 1940s, about 140 leopard *Panthera pardus* were killed in the Cederberg (Western Cape Province) alone (Stadler, 2006). Currently, every year, about half a million wild birds and mammals die from indiscriminate poisoning in South Africa (Woodroffe et al., 2005).

The existing research concerning DCAs concentrates on flagship species (Balme et al., 2010). Such leading flagship species throughout Africa and Asia include the African lion (Matema and Andersson, 2015; Ogutu et al., 2005), African elephant (Sitienei et al., 2014; Whitehouse and Kerley, 2002), leopard (Millspaugh et al., 2015; Swanepoel et al., 2014) and

tiger *Panthera tigris* (Das et al., 2012; Miller et al., 2015). Yet, problem animals that persist outside PA boundaries, such as the vervet monkey *Chlorocebus pygerythrus* (Saj et al., 2001), chacma baboon *Papio ursinus*, Cape vulture *Gyps coprotheres* (incidentally and deliberately poisoned by livestock farmers; Margalida et al., 2014), warthog *Phacochoerus africanus*, bush pig *Potamochoerus larvatus* and smaller mammals have received less attention. In addition, the olive baboon *Papio anubis* is an unpredictable raider that eats maize at any time and destroys more than it eats (Hill, 2000), and the greater cane rat *Thryonomys swinderianus* is a common raider of maize, accounting for a high percentage of crop loss (Nchanji, 2000). According to Bragg et al., (2005), the Cape porcupine does not only depredate maize and potato *Solanum tuberosum* crops but also damages fences and polyvinyl chloride water pipes. No attempts have been made to quantify the levels of damage by other mammals. Furthermore, the impact of preventative and deliberate killing of other mammals is also unknown (Bragg et al., 2005; Priston and McLennan, 2013).

Attitudes and perceptions towards wild animals

A reliable system of identification of problem animals and effective governance over DCA control is required for effective HWC mitigation (Abram et al., 2015). Often, farmers' perception of the most destructive species is influenced by factors other than damage to crops or livestock (Abram et al., 2015; Naughton-Treves, 1999; Nyirenda et al., 2013). According to Siex and Struhsaker (1999), the association of wildlife with damage is embedded so much in the minds of local rural communities (human settlements contiguous with PAs) in Zanzibar that they even blame beneficial species for damage. Barnes (1996) documented the attitude of people living in Central African forests to elephants as antipathetic, describing people's attitudes as 'ingrained hostility, animosity and hatred'.

Reducing the deliberate killing of wild animals by people hinges on improving attitudes and perceptions to wildlife and conservation issues (Anthony, 2007). In South Africa, negative attitudes to problem animals persist among farmers of livestock and game, especially towards the African wild dog, hyena *Crocuta crocuta*, African lion and cheetah (Lindsey et al., 2005). African wild dogs in particular have been stigmatised as 'terrorist' and 'cruel' due to their hunting technique and killing method of gutting the abdomen and disembowelling prey (Lindsey et al., 2005; Woodroffe and Ginsberg, 1998). These perceptions have led to the active persecution of wild dogs outside PAs even today (Davies-Mostert et al., 2015). However, fostering trust and communication between people and

conservation authorities has been shown to generate promising results in improving perceptions and transforming the attitudes and behaviour of local human communities in conflict with wildlife (Madden, 2004). Therefore, future conservation efforts depend on understanding the attitudes and changing the perceptions of people towards wildlife in conjunction with identifying problem animals and levels of damage.

Compensation for human-wildlife-conflict-related reparations

Compensation schemes that aim to mitigate HWC are contentious (McManus et al., 2014; Mishra et al., 2003). State-funded HWC compensation programmes are based on offering reparations or reimbursements for wildlife-depredation losses (Hemson et al., 2009). The main objective of such programmes is not to prevent depredation of crops and livestock but to dissuade lethal control of DCAs, encourage tolerance of losses and attempt to buffer the economic impact of such losses (Naughton-Treves, 1999). Governments and PA authorities, especially of developing countries, do not have the financial or administrative capacity to compensate farmers adequately for damage or loss induced by wild animals (Naughton-Treves, 1999).

Compensation schemes are often criticised for being ineffective and protracted (Hemson et al., 2009), and unrealistic expectations of compensation for wildlife-related depredations could lead to further enmity and negative attitudes towards wildlife (Boonzaier, 1996). When claims of damage are lodged, a process of validation is required and often in practice, authorities attend to the scene as late as two weeks after the incident (Hemson et al., 2009). Importantly, conservation authorities argue that compensation programmes discourage animal husbandry and decrease herd vigilance and that farmers should be compensated for implementing precautionary measures rather than livestock/crop damage (Hemson et al., 2009). Expensive fencing or employment of game guards is not always feasible, especially for poor homesteads (Naughton-Treves, 1999). The South African Cheetah Compensation Fund is the only programme to offer wildlife-depredation related reimbursements to commercial livestock and game farmers in South Africa for livestock damages, which is based on a rate of US$1,000 for every cheetah legally caught and relocated to an appropriate PA (Cilliers, 2003; Johnson et al., 2010; Lindsey et al., 2009).

Subsistence farmers, rural livelihoods and human-wildlife conflict

Subsistence agriculture refers to farmers that cultivate sufficient food to feed themselves and their families and is a practice typical of developing countries without commercial gain (DeGeorges and Reilly, 2009; FAO, 2014; Kates and Dasgupta, 2007). Ndaeyo (2007) poses homestead/subsistence farming as one approach to meeting the requirements of a rapidly growing human population without impeding ecological processes. In Nigeria, subsistence farming contributed to food security; homestead gardens yielded 25 different fruit species and 39 different vegetable crops towards Nigeria's food output (Ndaeyo, 2007).

Since rural settlements are dependent on land for subsistence (Kates and Dasgupta, 2007), they are largely reluctant to surrender land to conservation authorities or tolerate the presence of wild animals on their land (Newmark et al., 1993). Consequently, enmity by subsistence farmers for conservation efforts is fortified by a combination of socio-economic issues, such as poverty, resource scarcity, hunting restrictions (DeGeorges and Reilly, 2009), damage to property and depredation of crops, poultry and livestock by wild animals (Dublin, 1995). Since HWC can have far-reaching socio-economic consequences, especially for rural communities, wildlife depredations have important impacts on such people (DeGeorges and Reilly 2009; Fabricius et al., 2004). In addition, the low income and resource scarcity of subsistence farmers serve to lower tolerance towards wildlife and increase the rate of retaliatory killings and persecution of wildlife (DeGeorges and Reilly, 2008; Treves, 2006).

Current conservation approaches in South Africa that aim to mitigate HWC in the agricultural sector neglect quantifying the loss of poultry, crops or livestock experienced by the subsistence farmer. Naughton-Treves (1999) determined that subsistence farmers and rural communities are notably affected by even isolated incidences of livestock depredation or crop raiding due to their impoverished circumstances and small-scale operations (Fabricius et al., 2004; Naughton-Treves, 1999). Nonetheless, the sum of food and milk loss through livestock depredations threatens food security for subsistence homesteads, and repercussions could possibly extend to the family's nutrition, health and education (DeGeorges and Reilly, 2009; Naughton-Treves, 1999; Treves et al., 2006).

Importantly, subsistence and rural livelihoods are particularly vulnerable to changes in climate and environmental factors such as drought, floods and soil erosion (Kates and Dasgupta, 2007). These factors cumulatively threaten food security and exacerbate poverty and hunger (FAO, 2015; Kates and Dasgupta, 2007). It is estimated that approximately 700 million people in Sub-Saharan Africa live below the poverty line (i.e. live on less than

US$1.25 per day; Thornton et al., 2011; World Bank, 2013). Food security is one index of measuring poverty and is defined as access to safe, nutritious food to meet the requirements of a household year-to-year (Ndaeyo, 2007; World Bank, 2013).

South Africa is a water scarce country and coupled with the changes in Sub-Saharan climate that are currently due to the strongest El Niño event in decades (Gan et al., 2015), has resulted in below-average rainfall and soaring temperatures across the African continent (Gachene et al., 2015). Although El Niño is characterised by the increase in surface temperatures of the equatorial Pacific Ocean (Gan et al., 2015), researchers maintain that the occurrence of droughts in Sub-Saharan Africa are caused by physical elements associated with the El Niño phenomenon thousands of kilometres away (Gan et al., 2015). The impacts of heat stress and water scarcity are likely to be considerable in Africa because of the high rates of poverty (Thornton et al., 2011) and the reliance on subsistence agriculture for nutrition (Gachene et al., 2015), which could potentially affect health and food security (Gachene et al., 2015; Thornton et al., 2001). South Africa in particular is experiencing severe drought in the KwaZulu-Natal and the Free State Provinces, with sugar cane and maize crops consequently showing severe growth stunts (Gan et al., 2015). Approximately three million rural subsistence households in South Africa from the Eastern Cape, KwaZulu-Natal and Limpopo Provinces are affected by drought (Department of Agriculture Forestry and Fisheries, 2010). Drought intensifies the effects of wildlife depredations of farming commodities and threatens food security at household levels. Tensions between farmers and conservation authorities are expected to intensify when crops that survive abiotic problems (Tweheyo et al., 2005) such as drought become vulnerable to damage by crop-raiding mammals at the critical stage of harvest.

Motivation for the study

Human-wildlife conflict is of particular significance in developing countries where approximately 700 million people are on the brink of starvation (Hill, 2000; Thornton et al., 2011) and face adverse climatic conditions. The loss of crops and stored grain to elephants, rodents, primates, ungulates and birds, for example, further exacerbate poverty and food insecurity (Anthony, 2006; Gilbert and Dodds, 2001; Hill, 2000). Furthermore, incidences of HWC in South Africa and their effect on commercial farmers are increasingly being reported (Thorn et al., 2012; Van Niekerk, 2010), whilst subsistence farmers have been overlooked. Yet, little is known about how subsistence households in South Africa, an historically

disenfranchised (Cock and Fig, 2000; Khan, 1994) and economically vulnerable demographic (Armstrong et al., 2008), are affected by HWC (DeGeorges and Reilly, 2008). My research is exceptional, the first to consider whether and how the dichotomy of first- and third-world economies in South Africa (Armstrong et al., 2008), exemplified by commercial and subsistence farmers respectively, respond to HWC. This scenario is unique to South Africa where marginalised, rural, black subsistence farmers often farm alongside commercial farmers amidst one of the densest biodiversities in the world, and this provides an opportune setting for this study, making it possible to consider different farming practices (subsistence and commercial) in the same geographic location.

Aims and objectives

The broad aim of my study was to examine how subsistence and commercial farmers that ranched or cultivated in the same geographic area were affected by and responded to problem animals in selected localities of north-eastern South Africa (Fig. 1). This broad goal was established to quantify the similarities and differences in HWC, as experienced by subsistence and commercial farmers, and to quantify levels of threats and vulnerabilities to wildlife. I commenced my investigation with a meta-analysis of the occurrence of published scientific reports of human-wildlife conflict globally and specifically in South Africa (Chapter 2), to verify whether subsistence and commercial farmers were pertinent representatives for developed and developing agriculture economy comparisons, and these findings were used to shape data chapters for the remainder of the thesis. I assessed the responses of subsistence and commercial farmers using semi-structured questionnaire interviews and site inspections (Chapters 4-5). In addition, I identified leading DCAs associated with the greatest number of depredation incidences and investigated whether or not these DCAs were common to subsistence and commercial farmers (Chapter 5). Further, I gauged the attitudes and opinions of subsistence and commercial farmers to wildlife and conservation issues (Chapter 6), assessed the attitudes and opinions of conservation practitioners towards people living on PA boundaries (Chapter 7) and investigated farmer-African wild-dog conflict (Chapter 8), as a case study, to assess the movement patterns of wild dogs in areas in which they are lethally persecuted.

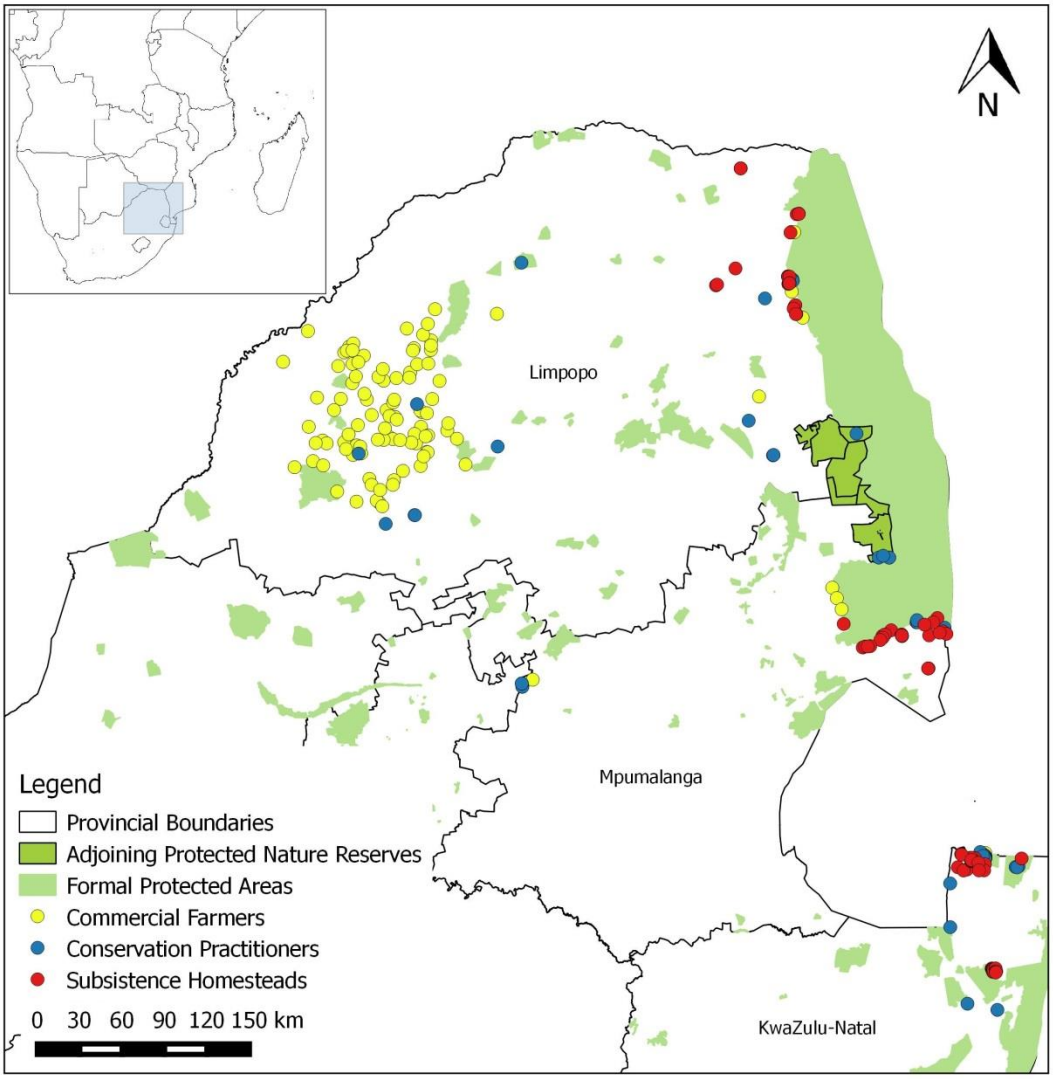


Figure 1. Study site map showing respondents in the north-eastern region of South Africa that participated in the study. A map of southern Africa is provided in the inset.

Structure of the thesis

This study consists of nine chapters, including a general introduction (Chapter 1), a literature review presented as a global-meta-analysis of human-wildlife conflict (Chapter 2), a general methods chapter (Chapter 3), five experimental chapters (Chapters 4 to 8) and a general discussion chapter (Chapter 9) in which I present my findings, final arguments, recommendations and conclusions. Each experimental chapter is freestanding and self-contained for publication in an Institute for Scientific Information-indexed journal. Each chapter is organised with an abstract, introduction, methods section (for specific procedures), results section, discussion, list of references and supplementary material. There may be some overlap of information in the introduction and discussion across the chapters. A separate list

of references complements each chapter; hence, there is some similarity in referencing between chapters. Tables and figures are also numbered consecutively within each chapter. The pages for the entire thesis are numbered consecutively, while line numbers are provided continuously within the chapters.

Glossary of terms

Apartheid. An official government policy of racial segregation formerly practised in the Republic of South Africa that involved economic, legal and political discrimination against black people into second-class citizens who were restricted geographically, educationally, socially and professionally (Khan, 1994; Cock and Fig, 2000).

Commercial farmer. A farmer or enterprise that cultivates crops or produces poultry, livestock or game for sale with the objective of making a profit (Thorn, 2015).

Conservation practitioner. Individual employed at protected areas (game reserves, lodges, national parks), involved in the management of ecological resources, such as university or technikon trained individuals in the fields of Zoology, Botany, Nature Conservation or Ecotourism Management, and excludes maintenance workers (Driver et al., 2012).

Crop-raiding. The feeding or destruction of cultivated food by wild animals that causes significant loss of food and income to farmers (Hill, 2000).

Damage-causing animal (DCA). A wild mammal that: i) causes losses of poultry, livestock or game; ii) causes excessive damage to cultivated crops and orchards; and iii) poses a threat to human safety when interacting with subsistence or commercial farmers (Stadler, 2006; Woodroffe et al., 2005).

Depredation. The consumption of agricultural resources (crops, livestock and game) by wild mammals (Woodroffe et al., 2005).

Developed (first-world) country. An industrialised country with a well-developed economy and advanced technological infrastructure relative to other less industrialised countries. The common benchmarks for evaluating the degree of economic development are the GDP, the level of industrialisation, the amount of infrastructure and the general standard of living (FAO, 2015; World Bank, 2013).

Developing (third-world) country. A nation with an underdeveloped industrial base and characterised by people with a reduced life expectancy and lower income compared with developed nations (FAO, 2015; World Bank, 2013).

Edge. A boundary or interface between a protected area and a landscape element (human settlement or farmland) (Woodroffe and Ginsberg, 1998).

Food security. A state in which all people at all times have access to sufficient, safe and nutritious food in order to maintain a healthy and active life (FAO, 2015).

Gross domestic product (GDP). A nation's total annual fiscal activity (or the monetary value of all the finished goods and services generated within a nation's geographic boundaries) (World Bank, 2013).

HWC hot spot. A biogeographic region in which significantly high incidences of human-wildlife conflict occur (Harvey et al., 2008).

Local community. People living adjacent or contiguous to protected areas or reserves, who may or may not subsist through farming (Hill, 2000).

Problem animal. A free-living native animal whose natural behaviour, temperament or habits bring it into conflict with humans (Stadler, 2006).

Protected area (PA). A biodiversity conservation area that receives protection due to the presence of indigenous wild fauna and flora that offers great ecological value (Graham et al., 2005).

Subsistence farmer. A farmer whose agricultural and livestock products are intended to provide for the basic needs of the farmer and his/her family and bring no profit, allowing only for a marginal livelihood (farming without profit from agricultural or livestock activities) (Hill, 2000).

Wildlife. This study considered undomesticated terrestrial vertebrate and invertebrate animals

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CHAPTER TWO

A meta-analysis of human-wildlife conflict: South African and global perspectives[1]

Abstract

Human-wildlife conflict, due to competition for shared natural resources between people and wild animals, is a contentious and complex issue in developing countries that affects a wide variety of people from different social and economic classes. We conducted a meta-analysis of the occurrence of published scientific reports on human-wildlife conflict globally, with reference to South Africa in particular, to assess: 1) common trends in vulnerable human communities and their farming practices in developing and developed countries; and 2) vulnerable wildlife guilds. Institute for Scientific Information journals were sourced from the years 1994 to 2015, generating 271 papers that exclusively reported either free-living mammals or birds in conflict with humans; while other taxonomic groups were poorly represented. We classified vulnerable human communities into subsistence farmers, commercial farmers and local communities. Local communities contiguous with protected natural areas were most affected (by 49 different wildlife species globally), followed by subsistence farmers and then commercial farmers. Additionally, local communities and commercial farmers jointly experienced the highest number of human-wildlife conflict incidences (n = 93 and n = 67 respectively) when compared with subsistence farmers (n = 38). Commercial farmers occupied a more prominent conflict profile, greater than that of the presumably vulnerable subsistence farmers, possibly due to the greater research focus on commercial farmers. Rural people in Africa and Asia experienced conflict with the widest diversity of mammals, confirming our expectation that developing countries could potentially experience regular encounters with wildlife. South Africa demonstrated greater numbers of human-wildlife conflict cases than developed regions, such as Australia and North America. The dichotomy between first world and third world economies in South Africa provides a regional exemplar of global patterns in human-wildlife conflict. Globally, carnivores and

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The descriptions of the contributions of the authors were as follows:
N. Seoraj-Pillai: Primary author, conducted data analysis, developed review concepts and the write-up.
Neville Pillay: PhD Supervisor, who provided the theoretical approach for the review and commented on various drafts of the manuscript.

primates were the most high-scale conflict species (featuring in ≥ five published papers in the database, reportedly depredating on livestock, crops or people), and thus, are a severely persecuted group globally. We concluded that developing countries experienced the highest incidences of HWC, particularly between local communities and a large diversity of mammals. Deficiencies in the reporting of lethal control, the involvement of a wider array of taxonomic groups and the vulnerabilities of poorer communities and farmers need attention in future.

Keywords: carnivores, high-scale conflict species, local communities, primates, subsistence farmers

Introduction

The escalating growth of the human population has increased demands for natural resources and fossil fuels (Boon, 2011). During the 20th century alone, the human population has increased from 1.65 billion to 6.5 billion people, with a potential of reaching 8 billion people by 2025 (Thornton et al., 2011; UNDP, 2008). As a result, human-dominated landscapes have intensified natural habitat degradation and fragmentation, and wildlife populations are now in regular competition with people for resources, thus eliciting 'human-wildlife conflict' (HWC). In this study, HWC denotes any instance in which the resource demands of humans and wild animals overlap, spurring competition for food, space and water and thus creating tension between people and wildlife (Peterson et al., 2010; Woodroffe et al., 2005).

Human-wildlife conflict is a global issue in both developed and developing countries (Treves and Karanth, 2003; Woodroffe et al., 2005). However, characteristics of HWC incidences are dependent on the type of resident wildlife in the region and the farming practices that are typical for that area. Wildlife in North America and Europe has been either extirpated or has experienced major geographic range collapses through hunting and persecution by people (Woodroffe et al., 2005). In most developed countries today, HWC is typified by large mammalian carnivores and commercial farmers (Naughton-Treves et al., 2003; Vktersø et al., 1999) due to extant wildlife assemblages. Examples include the brown bear *Ursus arctos*, the lynx *Lynx lynx*, the gray wolf *Canis lupus* and the wolverine *Gulo gulo*, all of which predominantly depredate commercially farmed sheep *Ovis aries* and/or cattle *Bos taurus* (Naughton-Treves et al., 2003; Vktersø et al., 1999). Such developed countries include Italy, Norway (Vitali 2014; Vktersø et al., 1999), the United States of America (USA)

(Naughton-Treves et al., 2003), Canada (Treves et al., 2006) and Australia (Burns, 2006, World Bank, 2013).

Developing countries, such as India (Chartier et al., 2011), Cameroon, the Central African Republic, Congo, Equatorial Guinea, Gabon (Barnes, 1996), Uganda (Hartter, 2009) and Bhutan (Sangay and Vernes, 2008), experience a wide variety of HWCs when compared with developed countries (Treves and Karanth, 2003). Examples include regular crop-raiding by non-human primates (hereafter primates), mega-herbivores (large-bodied herbivores), omnivores (e.g. wild boar *Sus scrofa*) and small mammals (e.g. cane rat *Thryonomys swinderianus*; Barnes, 1996; Hill, 2000). Poultry depredation by mongoose *Herpestes* spp. and jackal *Canis* spp. are typical occurrences in Tanzania (Holmern and Røskaft, 2013). Human and livestock depredation in developing countries due to carnivores, for example, tiger *Panthera tigris* and the snow leopard *Uncia uncia* in India, leopard *Panthera pardus* in Zimbabwe, Tanzania and Pakistan and lion *Panthera leo,* are major sources of conflict (Carter et al., 2014; Kesch et al., 2015). Farmed game depredation by African wild dog *Lycaon pictus* (Gusset et al., 2008; Lindsey et al., 2005) are also common in developing countries such as Zimbabwe (Creel and Creel, 2002), Botswana (Schiess-Meier et al., 2007) and South Africa (Gusset et al., 2008; Lindsey et al., 2005). These occurrences suggest that the geographic distributions of wildlife populations together with farming practices are important predictors of HWC.

Rural poverty, protected areas, natural resources and human-wildlife conflict in Africa

Currently, Africa has over 3 000 protected areas (PAs), with approximately 50 biosphere reserves (PAs established to conserve the biological and cultural diversity of a region). Africa houses the world's largest reservoirs of wild animal populations in terms of density and diversity compared with the rest of the world (Chape et al., 2005; DeGeorges and Reilly, 2008). Some scholars believe that these PAs were established at the cost of local livelihoods (Anthony, 2007; Cock and Fig, 2000; DeGeorges and Reilly, 2008). In the late 19th century, corresponding to outbreaks of rinderpest, unregulated hunting of wildlife and indigenous habitat clearing for farmland (Keller and Golley, 2000), urgent efforts to conserve natural resources and establish PAs were made by colonial governments (DeGeorges and Reilly, 2008; MacKenzie, 1997). It is estimated that about 50% of PAs worldwide have been established on land traditionally occupied and used by indigenous people (MacKenzie, 1997). Throughout Africa, thousands of indigenous people were evicted to accommodate the

establishment of PAs (Carruthers, 1995; Cock and Fig, 2000; DeGeorges and Reilly, 2008) and compressed into impoverished communities bordering PAs, and many of these communities exist still today (Anthony, 2007). Currently, the livelihoods of local human communities residing on the edge of these PAs often involve the direct exploitation of natural resources (Anthony, 2007), bringing the communities into conflict with wildlife and park authorities.

According to the Food and Agricultural Organization of the United Nations (FAO) (FAO, 2015), Sub-Saharan Africa is dominated by smallholder subsistence farms, cultivating a mixture of crops corresponding to different soil and water regimes. Human pressure on soil health has left a third of all soils on which crop production depends, degraded worldwide (Roser, 2015). In Sub-Saharan Africa, ~180 million people are affected by land degradation (FAO, 2015; Roser, 2015) due to damaged soils that impede crop yields. Additionally, African pastoralist communities mostly live in remote and underdeveloped areas that are plagued by drought and disease (UNDP, 2008); therefore, these areas are associated with high levels of vulnerability to food insecurity (Roser, 2015). Pastoral areas in Africa occupy about 40% of Africa's land mass, with variations between countries (UNDP, 2008). Generally, pastoral areas are less suitable for crop production, and livestock husbandry remains the most common farming practice in arid regions of Africa (Roser, 2015).

South Africa is undergoing transition and reform with a contentious and distinct socio-economic and political history of racial segregation under the apartheid government (Anthony et al., 2010; Cock and Fig, 2000). South Africa is also a unique country of dualities in which first-world, wealthy and stable industries and third-world, underdeveloped sectors occur concurrently, and this is exemplified in the agricultural sector that comprises subsistence households and commercial farmers (Armstrong et al., 2008) farming within the same geographic area. Approximately 20% (2.9 million) of all households in South Africa are subsistence households (Statistics South Africa, 2011) that are compressed into racially segregated settlements in poor-farming areas (Cock and Fig, 2000; DeGeorges and Reilly, 2008). Commercial farmers dominate in particular provinces within South Africa, such as the Free State with ~10 000 farms, the Western Cape with ~8 300 farms and the North West Province with ~7 500 farms (Statistics South Africa, 2011). In contrast, Ebedes (2002) reported that the approximately 7 000 privately owned game farms in South Africa occupy 16 million hectares of land. Importantly, while commercial agriculture generates R30 billion (~US$1.8 billion, where one ZAR = US$0.062) in profits annually, the game-farming industry turnover accumulated R105 million (~US$6.5 million) in the same period. In

comparison, many of the households involved in subsistence agriculture, which far outnumber commercial and game farms, have limited income and depend on their farming efforts to ensure food security (Statistics South Africa, 2011).

Most of the land in South Africa is only suitable for grazing (84 million hectares) and, due to soil aridity (Turpie et al., 2002), only 13.5% can be used for crop production (DeGeorges and Reilly, 2008). Commercial farming comprises livestock farming, game farming, field crops and horticulture (DeGeorges and Reilly, 2008). Livestock keeping in South Africa consists predominantly of poultry and egg production, followed by red meat and dairy production, while crop and horticulture production predominantly consist of maize *Zea mays*, sugar cane *Saccharum* spp., potato *Solanum tuberosum*, wheat *Triticum aestivum*, and deciduous and citrus fruit (DeGeorges and Reilly, 2008; FAO, 2015).

In South Africa, several abiotic factors challenge farming efforts, namely decreasing soil fertility, low rainfall, increasing soil salinity and greenhouse gas emissions from livestock. Drought and famine have had devastating effects in southern Africa periodically (Turpie et al., 2002). The most severe droughts for the summer-rainfall region of South Africa occurred in 1982/1983, with crop loss amounting to about R2.2 million (~US$136 700), and resulting in a drop in the Gross Domestic Product (GDP) by 7%. Similar impacts on GDP occurred in the 1992 drought (Rouault and Richard, 2003). During those periods of environmental stress, incidences of HWC also intensified. For example, the alleged damage caused by Chacma baboon *Papio ursinus* to timber plantations in South Africa increased during the 1982/1983 droughts, when these baboons utilised alternate food sources such as commercially farmed pine *Pinus* spp. trees. These incidences did not re-occur until the 1993/1994 droughts (Fergusson, 2005; Lamarque et al., 2009). Environmental and climatic factors, therefore, increase opportunities for HWC, which manifest into crop and livestock damage (Fergusson, 2005; Lamarque et al., 2009).

In South Africa, approximately 30% to 55% of poor, local community members reported HWC occurrences due to problem animals from neighbouring PAs (Spenceley, 2005). Crop-raiding by elephant *Loxodonta africana* and baboon and livestock depredation by lion and spotted hyena *Crocuta crocuta* were reported (Spenceley, 2005), while sporadic incidences involving large carnivore attacks on people were also documented (Spenceley, 2005). Frequent episodes of crop-raiding were associated with harvest time, the most critical and vulnerable period for those impoverished households (Spenceley, 2005). These findings indicate serious conservation and socio-economic issues that warrant further investigation.

There have been several international efforts to conserve cultural and natural amenities in developed countries, to increase the popularity of a destination through scenery and outdoor recreation (Thorsell and Sigaty, 2001). Wildlife densities in such developed countries, however, remain low due to historical extirpations and several land-use changes (mining, farming, industrialisation; Hansen and Rotella, 2001). In contrast, developing countries on the African continent contain 25% of the global mammal species, including about 80 species of antelope and > 2000 bird species. In addition, Africa is home to 24% of the 34 global biodiversity hotspots (World Resource Institute, 2016). South Africa, in particular, houses the third highest level of biodiversity globally (DeGeorges and Reilly, 2008) and presents a unique scenario to investigate HWC due to the prevalence of commercial farmers and local subsisting communities competing with PAs for critical natural resources.

The aim of our study was to investigate the occurrence of HWC globally and subsequently in relation to South Africa in order to assess common trends in vulnerable human populations, their farming practices and vulnerable wildlife guilds (e.g. carnivores and mega-herbivores). This was achieved through a meta-analysis of published scientific literature from 1994 to 2015 indexed through the Institute for Scientific Information (ISI). Specifically, we 1) catalogued the global distribution of HWC from scientific publications; 2) assessed the numbers and types of HWC incidences experienced by different types of people (i.e. subsistence farmers, commercial farmers and local communities) in developed and developing countries; 3) identified damage-causing animals (DCAs); 4) gauged the vulnerability of DCA species. In addition, we 5) investigated the relationship between natural feeding behaviour of DCAs and types of depredation associated with the greatest number of HWC incidences. We made three predictions**.** 1) Subsistence farmers would experience a higher number of depredation incidences than commercial farmers. This might be due to subsistence farmer's close proximity to PA edges and the inability of poor households to afford wildlife-proof deterrents. 2) Mega-herbivores, primates and carnivores would feature prominently as DCAs in the literature database. This might be due to their broad geographic distribution and their ability to transgress PA boundaries. Although small mammals can transgress boundaries, mega-fauna (large-bodied mammals) cause damage that is more noticeable over a short period. 3) Farmers in developing countries would be affected by a wider diversity of DCAs than farmers in developed countries. This might be due to the prevalence of dense and diverse wildlife reservoirs in, for example Africa and Asia, and the inability of poor communities to afford fencing for their gardens and pastures.

Materials and methods

Literature survey and sourcing of data

A systematic review of the scientific literature on HWC was conducted using guidelines outlined by Pullin and Stewart (2006) and Inskip and Zimmermann (2009) with various search engines and data sources to establish the current scientific knowledge concerning HWC on a global scale and subsequently South Africa specifically. The review involved a pre-defined search protocol using filters for keywords to audit search relevance and applicability (Pullin and Stewart, 2006). Literature containing the phrase 'human-wildlife conflict' was searched with Google Scholar (accessed June 2014 and July 2015). The initial search on Google Scholar alone yielded 206 000 search results. We thereafter limited searches to published scientific articles only, using the snowball method of reference harvesting from web-based search engines, such as the University of the Witwatersrand e-Wits Catalogue http://innopac.wits.ac.za/; http://www.jstor.org, www.elsevier.com; www.sciencedirect.com; link.springer.com/journals; and https://www.academicjournals.org. We further limited selection to published scientific articles containing two or more of the following keywords or phrases relevant to HWC in the title or abstract of each publication: human-wildlife conflict, mitigation, pastoralist, subsistence farming, commercial farming, communities, crop-raiding, livestock depredation, retaliatory killing, persecution, compensation, attitudes and perceptions. This protocol ensured high levels of recall or relevance for a systematic review. In addition, given the paucity of older HWC publications (since the 1800s until 1993, only five other publications with the phrase 'wildlife conflict' appeared in the title of the publication), we considered studies from 1994 onwards. Hence, we provided a review of the past 22 years (1994 to 2015) only, which represented 98% of the literature with 'wildlife conflict' in the title of the publication since the 1800s.

Each publication that investigated a single DCA species/type (depending on detail), was recorded as a single incident per site. If the publication investigated more than one species of DCA, we considered each species as a separate incident per site. Hence, each DCA represented one data point. The collated literature was chronologically organised into a spreadsheet and examined under the following categories: author; year of publication; keywords; location; and Global Positioning System (GPS) co-ordinates of the study area (discussed later). Other categories examined included study species and conflict interfaces, that is, subsistence farms, commercial farms, pooled farms (case studies where data for subsistence and commercial farmers were pooled and not compared) and local communities

(where scientific articles did not specify whether or not people living adjacent to PAs farmed). We acknowledge that the data set may be prone to biased reporting and relate to specific cases that have been reported in the literature using particular terminology. It is possible that some countries may use terms, keywords and phrases that are atypical and hence limit the findings of the meta-analysis. In addition, the data-set could be biased towards English-speaking countries. We thus limit conclusions based on the applicability of our data set. In addition, we acknowledge that the meta-analysis contains data derived from articles that provide original observations as well as those articles with synthesised data derived from secondary sources and hence it is possible that the data set could be prone to some degree of misinterpretation.

Mapping of human-wildlife conflict studies using geographic information systems

For study sites where the GPS co-ordinates were not provided, these co-ordinates were obtained using an online geo-referencing tool: http://www.gps-coordinates.net. In these cases, the midpoint of a PA or study site was used to derive their GPS co-ordinates. All GPS co-ordinates were converted to decimal degree format with latitude and longitude co-ordinates captured separately for importation into Quantum GIS (QGis) 2.8.1 for geographic information system (GIS) analysis. The shape file was obtained from the South African National Biodiversity Institute (SANBI) and the Biodiversity Geographic Information System (BGIS) database (http://bgis.sanbi.org/index.asp?screenwidth=1600). The shape file was used as a base layer and opened first, onto which conflict study sites were overlaid. Hence, to examine the historic progression of studies concerning HWC, two separate maps were constructed to show studies from 1994 to 2000 and 2001 to 2015. To examine the distribution of different conflict species, GIS maps concerning species-level conflict were also generated in order to position the existing literature geographically. A separate map was also produced to examine the different groups of wild fauna studied from 1994 to 2015 in Sub-Saharan Africa only. This would spatially highlight the HWC hot spots.

Gauging species vulnerability

To assess species vulnerability to conflict and to gauge the predisposition or susceptibility of species for depredation, wildlife that appeared in the data set was divided into low-, moderate- and high-conflict species. A description of how species were categorised for vulnerability and conflict status is provided in the supplementary material (**Supplementary material:** Table S1) using guidelines proposed by Gittleman et al., (2001)

and Inskip and Zimmermann (2009). These weightings considered the levels of biodiversity extinction vulnerability with corresponding acronyms for classification (**Supplementary material:** Table S1). In their review of human-felid conflict, Inskip and Zimmermann (2009) provided guidelines for gauging the index of vulnerability and the conflict status of carnivore pest species based on the number of times that a study species appeared in the literature (**Supplementary material:** Table S2).

The cut-off levels provided in our study were adapted from Inskip and Zimmermann (2009). If a species appeared only once in the database, it was categorised as 'poorly researched' or 'low-scale conflict' (LSC) species and assigned the acronym PR for their vulnerability index. Low-scale conflict species are wild animals that rarely attack people, seldom depredate livestock or crops and experience rare retaliatory killings. Examples of LSC species include the sun bear *Helarctos malayanus*, black howler monkey *Alouatta caraya*, European rabbit *Oryctolagus cuniculus*, and greater flamingo *Phoenicopterus roseus*. If species appeared two to four times in the database, they were classified as a 'medium or moderately persecuted' (MP) animal or 'moderate-scale conflict' (MSC) species. Moderate-scale conflict species are wildlife that rarely attack people but may frequently depredate livestock or crops and experience frequent retaliatory killings, for example, Nilgai *Boselaphus tragocamelus*, American black bear *Ursus americanus*, and Asiatic jackal *Canis aureus*. If animals appeared five or more times in the data set, such species were classified as a 'well-researched' or 'high-conflict' or 'severely persecuted' (SP) animal. High-scale conflict (HSC) species typically attack humans and experience high retaliatory persecution. Examples of HSC species include the African lion and brown bear *Ursus arctos*. If such endangered species did not appear in the data set but anecdotal evidence of conflict existed, they were categorised as 'conflict status unknown' (SU), and that future research (FR) or research required (RR) should be conducted for such species.

A species becomes vulnerable to extinction when it displays one or more of the seven characteristics (Gittleman et al., 2001, Purvis et al., 2000). These include: 1) reduction or severe fragmentation in its geographic range; 2) small, declining or low-density population; 3) low reproductive rate; 4) large home-range requirements; 5) reduced genetic variability; 6) special niche requirements; and 7) harvested by people for trophies, bush meat or pelts (Gittleman et al., 2001; Purvis et al., 2000). According to Gittleman et al., (2001), these characteristics of vulnerability are important predictors of extinction risks and levels of species imperilment. We subsequently cross-referenced our data set to that of the International

Union for Conservation of Nature (IUCN) Red List of Threatened Species to assess the conservation status of conflict species.

The level of taxonomic detail for species reported in each publication was inconsistent among publications in the database, with some authors providing species names and others only reporting the family name, for example, doves, family Columbidae. Hence, the detail in which our inventory of problem animals was dependent on the level of detail provided in each publication. Therefore, we reported the types of mammals and birds that appeared in the review and where possible, provide the binomial scientific name.

Statistical analysis

All statistical analyses were performed using R statistical software version 3.1.3, (R Core Team 2015); https://cran.r-project.org/bin/windows/base/old/3.1.3). Bar plots were produced through the R software GrapheR extension version 1.9-84 (Hervé, 2011). For all tests, co-efficient estimates, including the residual degrees of freedom (df), standard error, Z statistic and corresponding *P*-values were generated through a GLMM fit by maximum likelihood (with Laplace approximation) for both fixed and random effects using an lme4 extension (Bates et al., 2015) for fitting mixed-effects models. The GLMM with a Poisson error structure is appropriate for analysing count data that do not assume a normal distribution.

A GLMM was most appropriate to assess the impact of HWC on groups of people (local communities, subsistence and commercial farmers), because it is an extension to the generalized linear model, containing random effects (e.g. location) in addition to the typical fixed effects (e.g. subsistence and commercial farmers). All GLMMs were fitted via maximum likelihood, equivalent to the Akaike information criterion (AIC). In addition, the GLMM is ideal as it also allows the specification of models whose response variable follows non-normal/error distribution (e.g. counts of literature studies (Poisson), or binary distributions (yes/no or absent/present). Although several methods to analyse meta-data exist, we have used the GLMM as it allowed us to examine differences between and within regions.

The vulnerability of people and farming commodities

A generalised linear mixed model (GLMM) with a Poisson error structure with a log link function (e.g. for count data: number of publications, species, locations) was used to establish which types of people (fixed factors: subsistence farmers, commercial farmers and/or local communities) were more susceptible to depredation by low-, medium- or high-

scale conflict species (dependent variables). The model evaluated differences between the types of people affected by HWC and when such differences occurred, the GLMM relevel function showed the risk level or threat. All studies that discussed HWC management or policy frameworks but did not mention or include a specific study species were omitted from this analysis.

Analysing human-wildlife conflict studies in South Africa in relation to global studies

The data of reported HWC incidences and the DCAs responsible for those incidences of HWC were pooled for South Africa and compared with studies from the rest of Africa and elsewhere in the world. A GLMM model was used to establish differences between geographic areas or continents and when such differences occurred (1994-2015), the GLMM relevel function evaluated the level of threat (i.e. country experiencing a greater number of HWC incidences). Relevel functions re-order factors of interest so that the level specified by reference is first and the others are moved down. This technique is useful for contrasts which take the first level as the reference. For example, first level factors included differences between countries, and second level factors examined and reordered factors to reveal countries experiencing greatest to lowest number of HWC incidences.

Analysing feeding behaviour and depredation diet

To investigate the relationship between natural feeding behaviour of DCAs and the type of product (e.g. crop, livestock, game or poultry) depredated, we compared the natural feeding habits of the animals with their depredation diet. Damage-causing animals that appeared in the database were classified into five categories: 1) herbivore – feeds on plant matter, including grain, seeds, modified rhizomes, stems, leaves, buds, flowers, fruits and lichen; 2) bulk grazer – herbivores that feed on large amounts of grass only; 3) bulk feeder – herbivores that feed on large amounts of browse/euphylls or grass, or a combination of both; 4) carnivore – feeds on animal matter mostly; and 5) omnivore – animal that feeds on fungi, carrion, plant and animal matter. These feeding habits were compared with the type of crop (livestock, poultry or a combination of these) depredated during each case study in the literature. Natural diet and feeding behaviour information was obtained from the *Encyclopedia of Mammals* (Macdonald, 2009), *The Handbook of the Birds of the World* (Del Hoyo et al., 2013) and *Roberts' Birds of Southern Africa* (Hockey et al., 2005). Although categories 1-3 are all herbivores, I distinguished between feeding types 1-3 because they differ in forage quality and quantity (Owen-Smith, 2005). Species that only damaged property

such as fences were excluded from the feeding habit analysis but were included in the vulnerability of people and South Africa analyses.

Results

General human-wildlife conflict trends

A total of 271 scientific publications concerning HWC in peer-reviewed journals from 1994 to 2015 were consulted. The data set of scientific publications for the meta-analysis constituted 220 research papers investigating DCAs worldwide, and the remaining 51 papers contained reports, discussions, policy frameworks and recommendations regarding HWC. Examination of the published articles revealed 38 incidences affecting subsistence farms, 93 incidences involving local communities, 67 incidences affecting commercial farms and 22 cases involving pooled subsistence-commercial farmer data (denoted as pooled farmer data). Under the search criteria, animals that appeared in the literature database (excluding species whose conflict status was classified as unknown- SU – see **Supplementary material:** Table S1) comprised mainly mammals, including six types of antelope, 32 types of carnivores, five types of mega-herbivores, 25 types of primates and 15 types of species classified as other mammals. There were also 14 types of birds. The literature mostly reported mammals and birds whereas other taxonomic groups were under-reported. A comprehensive data set or inventory is available in **Supplementary material:** Tables S2. We pooled infrequently reported damage-causing mammals or non-specified damage-causing mammals into the group 'other mammals'.

Vulnerability of people and farming commodities

The data set showed that 45 different types of DCAs reportedly affected subsistence farmers, 49 different types of DCAs affected local communities, 37 different types of DCAs reportedly affected commercial farmers and 25 different types of DCAs affected pooled farmers. A similar number of HWC cases were reported for commercial farmers and local communities, while a larger number of HWC cases were reported for commercial farmers compared with subsistence farmers and pooled farmers (Fig. 1; Table 1). Similarly, local communities experienced a greater number of HWC incidences compared with pooled farmers and subsistence farmers, while subsistence farmers showed a higher number of

reported HWC incidences compared with pooled farmers (Table 1).

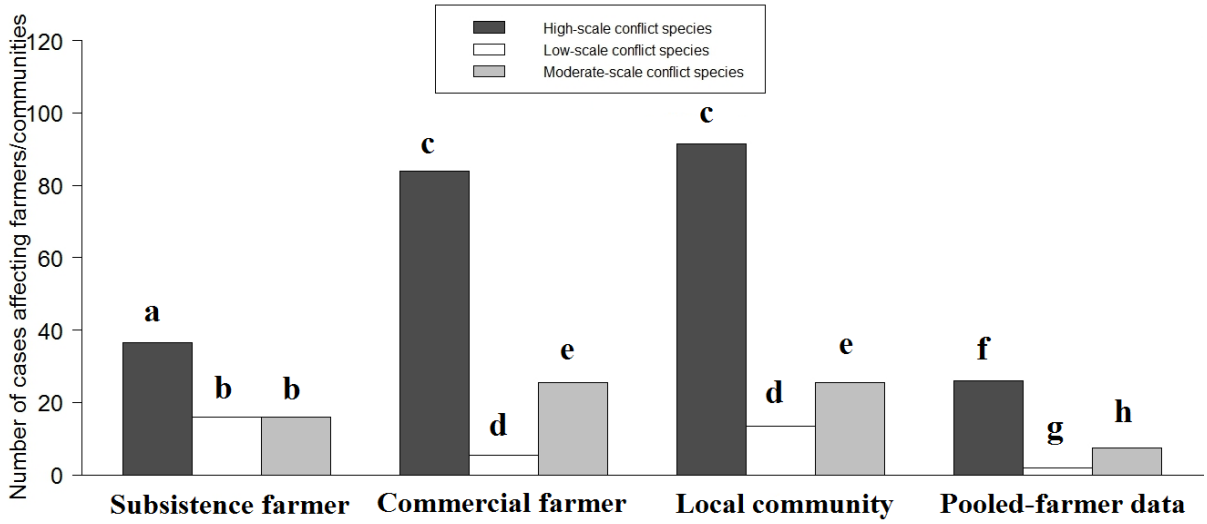


Figure 1. The prevalence of high-, low- and moderate-scale-conflict species and type of farmer or community affected from 1994−2015. Bars denote total number of human-wildlife conflict cases generated during the meta-analysis. Different letters above bars (representing the *P*-values of the linear mixed models generated in Tables 1-2) denote significant differences between different types of people affected by high-, low- and moderate-scale-conflict species.

Table 1. Generalised linear mixed model comparing how farmers and communities are affected by human-wildlife conflict worldwide. Model degrees of freedom, df=7.

Comparisons	**Farmer experiencing greater number of HWC incidences**	**Std. Error**	**Z value**	***P***
Commercial farmer vs Pooled farmers	Commercial	0.19	-6.27	<0.001
Commercial farmer vs Local communities	Similar	0.13	0.82	0.410
Commercial farmer vs Subsistence farmers	Commercial	0.15	-3.51	<0.001
Local community vs Pooled farmers	Local community	0.19	-6.90	<0.001
Local community vs Subsistence farmers	Local community	0.15	-4.28	<0.001
Subsistence farmer vs Pooled farmers	Subsistence farmer	0.20	-3.22	<0.001

Table 2. Statistical comparison of low-, moderate - and high-scale conflict species affecting farmers and communities worldwide. Model degrees of freedom, df=8.

Comparisons	**Dominant conflict species**	**Std. Error**	**Z value**	***P***
LSC vs HSC species	HSC	0.17	-10.69	< 0.001
MSC vs HSC species	HSC	0.13	-8.88	< 0.001
LSC vs MSC species	MSC	0.20	-3.37	< 0.001

Cases involving high-scale conflict species were more common than moderate- and low-scale conflict species (Fig. 1; Table 2). In addition, cases of moderate-scale conflict species were more common than low-scale conflict species (Fig. 1; Table 2).

Human-wildlife conflict studies in South Africa versus global studies

South Africa (number of HWC cases per DCA, *n* = 34) and Europe (*n* = 28) experienced similar trends in the number of HWC incidences in the literature (Table 3), whereas Asia (*n* = 87) and other parts of Africa (*n* = 180) showed a greater number of HWC incidences per DCA when compared with South Africa (Table 3). South Africa experienced a greater number of HWC incidences per DCA compared with Australia (*n* = 3), South America (*n* = 13) and North America (*n* = 13) (Table 3). Mega-herbivores, primates and other mammals did not differ in the numbers of HWC incidences in the database (Table 4). Carnivores were the main causes of damage, followed jointly by mega-herbivores and primates (Table 4). Interestingly, most of the HWC cases reported for South Africa were based around commercial farmers.

Table 3. Statistical comparisons of human-wildlife conflict incidences per damage-causing animal reported from South Africa in comparison with the rest of the world. Model degrees of freedom, df=34.

Comparisons (n= number of HWC cases per DCA)	**Country experiencing greater number of HWC incidences**	**Std. Error**	**Z value**	***P***
South Africa (n=34) vs Asia (n=87)	Asia	0.20	4.66	< 0.001
South Africa vs Australia (n=3)	South Africa	0.60	-4.05	< 0.001
South Africa vs Europe (n=28)	Similar	0.25	-0.76	0.450
South Africa vs North America (n=13)	South Africa	0.32	-2.96	0.003
South Africa vs Other parts of Africa (n=180)	Other parts of Africa	0.19	8.95	< 0.001
South Africa vs South America (n=13)	South Africa	0.32	-2.96	0.003

Table 4. Statistical comparison between damage-causing animals at each study site. Model degrees of freedom, df=35.

Comparisons	Vertebrate causing greater number of HWC	Std. Error	Z value	*P*
Carnivore vs Antelope	Carnivore	0.36	-8.91	< 0.001
Carnivore vs Bird	Carnivore	0.24	-9.76	< 0.001
Carnivore vs Mega-herbivore	Carnivore	0.17	-9.25	< 0.001
Carnivore vs Other mammals	Carnivore	0.18	-9.30	< 0.001
Carnivore vs Primates	Carnivore	0.15	-8.18	< 0.001
Mega-herbivore vs Antelope	Mega-herbivores	0.39	-4.10	< 0.001
Mega-herbivore vs Bird	Mega-herbivores	0.28	-2.58	0.010
Mega-herbivore vs Other mammals	Similar	0.23	-0.11	0.910
Mega-herbivore vs Primates	Similar	0.21	1.93	0.060
Other mammals vs Antelope	Other mammals	0.39	-4.02	< 0.001
Other mammals vs Bird	Other mammals	0.28	-2.48	0.013
Other mammals vs Primates	Primates	0.21	2.04	0.042
Primates vs Antelope	Primates	0.38	-5.28	< 0.001
Primates vs Birds	Primates	0.26	-4.24	< 0.001

Mapping of human-wildlife conflict studies

From the distribution of reported sites of HWC (Fig. 2), there was an 87% increase in reports of HWC in Africa and Asia from 2000 to 2015. In addition, there has been a 92% increase in reports of HWC in South America (Fig. 2). Interestingly, according to the meta-analysis, HWC in South Africa was only first documented in 2005 in an ISI-indexed journal. Maps illustrating the distribution of conflict species were generated (**Supplementary material:** Figs. S1–5) using data accessed from the literature.

Vulnerability of conflict species

Six types of antelope and 14 types of birds were classified as low- to moderate-scale conflict species (Table 5). Only the family names of most birds were reported. Carnivores comprised seven low-scale conflict species, ten moderate-scale conflict species and 15 high-scale conflict species (Table 5). Mega-herbivores comprised one high-scale conflict species (African elephant *Loxodonta africana*), two moderate-scale conflict species and two low-scale conflict species.

Other mammals (bushpig *Potamochoerus larvatus*, dhole *Cuon alpinus*, European bison *Bison bonasus*, European rabbit *Oryctolagus cuniculus*, feral domestic pig *Sus domesticus*, honey badger *Mellivora* spp., mongoose *Herpestes* spp., porcupine *Hystricidae*, rodents *Rodentia*, squirrel *Sciuridae*, Sulawesi warty pig *Sus celebensis*, warthog

Phacochoerus sp., wild boar *Sus scrofa*; Table 5) contained three high-scale conflict species, seven low-scale conflict species and five moderate-scale conflict species. The primates comprised 16 low-scale conflict species, four moderate-scale conflict species and five high-scale conflict species.

An assessment of the conservation status of conflict species yielded several high- to moderate-scale conflict species listed on the IUCN Red List (as at 2015). Carnivores featured prominently, posing high-scale conflict and consisting of the African lion (vulnerable), African wild dog (endangered), brown hyena *Hyaena brunnea* (near threatened), cheetah *Acinonyx jubatus* (vulnerable), jaguar *Panthera onca* (near threatened), leopard (vulnerable), snow leopard (endangered) and tiger (endangered). The dhole (endangered) and Himalayan black bear *Ursus thibetanus* (vulnerable) experienced moderate-scale conflict with humans. Mega-herbivore and primate red-listed species posing high-scale conflict in the literature database included the African elephant (vulnerable) and the orangutan *Pongo* spp. (critically endangered) respectively, and the Asian elephant *Elephas maximus* (endangered) showed moderate-scale conflict with humans. Although anecdotal evidence (Wikipedia, 2015; https://en.wikipedia.org) suggests that the endangered Hirola or Hunter's hartebeest *Beatragus hunteri*, the Amur leopard *Panthera pardus orientalis* and the northern muriqui (woolly spider monkey) *Brachyteles hypoxanthus* may elicit conflict with people and farmers due to competition for resources, no supporting evidence for such conflict appeared in the published literature database.

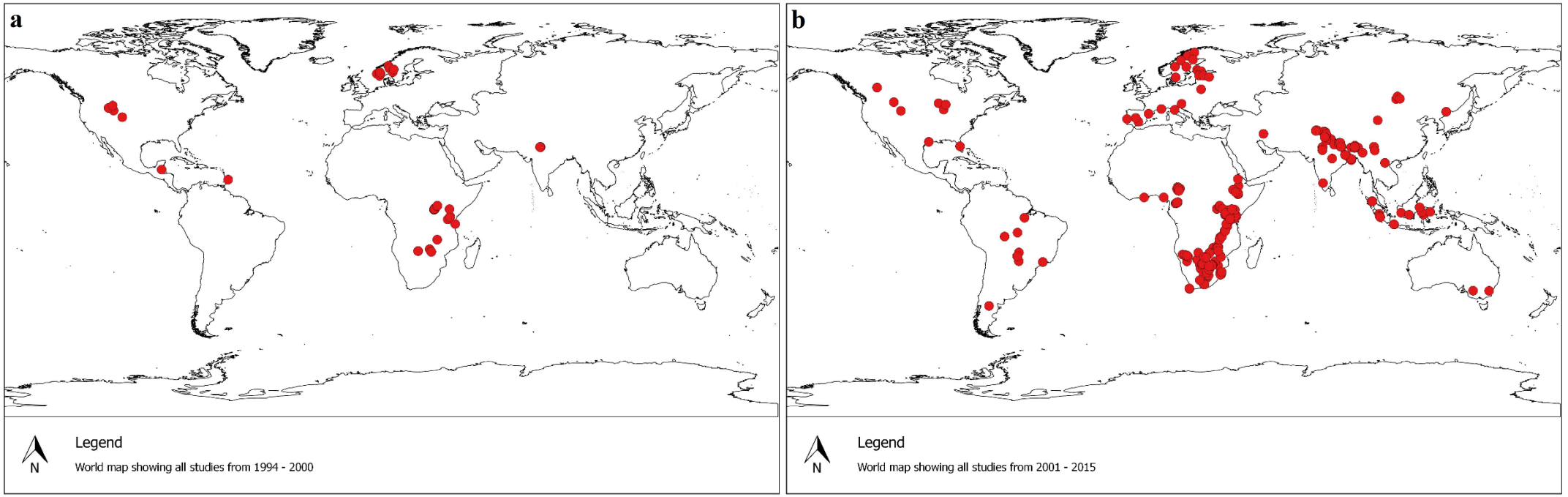


Figure 2. Comparison of the number of scientific publications concerning human-wildlife conflict in the database between a) 1994−2000 and b) 2001−2015. Red circles are global positioning system data points that represent human-wildlife conflict study sites, showing a substantial increase in publications of human-wildlife conflict in Africa and Asia over the two time periods and in previously under-reported South America.

Table 5. Vulnerability index and conflict status of problem animals that appeared in the human-wildlife conflict literature database. The common name, species name (where available), the International Union for Conservation of Nature status for each animal (as at 2015) and the number of publications in which each animal featured is included. Bold text indicates endangered species that do not appear in the database and hence, their vulnerability index requires assessment and their conflict status is unknown.

Common name of problem animal	Species	IUCN status	Number of publications	Vulnerability index				Conflict status
				PR	MP	SP	RR/ FR	
Antelope								
Eland	*Tragelaphus oryx*	Least concern	1	X				Low-scale
Hirola	*Damaliscus lunatus*	Critically endangered	**0**				**X**	**Status unknown**
Kudu	*Tragelaphus strepsiceros*	Least concern	2		X			Moderate-scale
Musk deer	*Moschus leucogaster*	Endangered	1	X				Low-scale
Nilgai	*Boselaphus tragocamelus*	Least concern	2		X			Moderate-scale
Roan	*Hippotragus equinus*	Least concern	1	X				Low-scale
Sitatunga	*Tragelaphus spekii*	Least concern	1	X				Low-scale
Birds								
Blackbird	*Turdus merula*	Least concern	1	X				Low-scale
Crane	Gruidae		2		X			Moderate-scale
Crow	Corvus		1	X				Low-scale
Dove	Columbidae		2		X			Moderate-scale
Flamingo	*Phoenicopterus roseus*	Least concern	1	X				Low-scale
Goose	Anserinae		2		X			Moderate-scale
Golden eagle	*Aquila chrysaetos*	Least concern	1	X				Low-scale
Green parrot	Trichoglossus		1	X				Low-scale
Partridge	Perdicinae		1	X				Low-scale
Pigeon	Columbidae		2		X			Moderate-scale
Raptor	Unspecified		2		X			Moderate-scale
Thrush	Turdidae		2		X			Moderate-scale
Vulture	Unspecified		1	X				Low-scale
Weaverbird	Ploceidae	Least concern	1	X				Low-scale
Carnivores								
African lion	*Panthera leo*	Vulnerable	21			X		High-scale
African wild cat	*Felis silvestris*	Least concern	1	X				Low-scale
African wild dog	*Lycaon pictus*	Endangered	14			X		High-scale
American black bear	*Ursus americanus*	Least concern	3		X			Moderate-scale
Amur tiger	*Panthera tigris altaica*	Endangered	1	X				Low-scale
Amur leopard	*Panthera pardus orientalis*	Critically endangered	**0**				**X**	**Status unknown**
Asiatic black bear	*Ursus thibetanus*	Vulnerable	2		X			Moderate-scale
Asiatic jackal	*Canis aureus*	Least concern	2		X			Moderate-scale
Asiatic wild dog/dhole	*Cuon alpinus*	Endangered	4		X			Moderate-scale
Black-backed jackal	*Canis mesomelas*	Least concern	8			X		High-scale
Brown bear	*Ursus arctos*	Least concern	7			X		High-scale
Brown hyena	*Hyaena brunnea*	Near threatened	5			X		High-scale
Caracal	*Caracal caracal*	Least concern	4		X			Moderate-scale
Cheetah	*Acinonyx jubatus*	Vulnerable	10			X		High-scale
Common jackal	*Canis aureus aureus*	Least concern	2		X			Moderate-scale

Common name of problem animal	Species	IUCN status	Number of publications	Vulnerability index				Conflict status
				PR	MP	SP	RR/ FR	
Ethiopian wolf	*Canis simensis*	Endangered	1	X				Low-scale
Eurasian lynx	*Lynx lynx*	Least concern	5			X		High-scale
Florida black bear	*Ursus americanus floridanus*	Least concern	1	X				Low-scale
Gray wolf	*Canis lupus*	Least concern	18			X		High-scale
Grizzly bear	*Ursus arctos*	Least concern	2		X			Moderate-scale
Himalayan black bear	*Ursus thibetanus*	Vulnerable	2		X			Moderate-scale
Iberian lynx	*Lynx pardinus*	Endangered	1	X				Low-scale
Jaguar	*Panthera onca*	Near threatened	5			X		High-scale
Leopard	*Panthera pardus*	Vulnerable	25			X		High-scale
Other Carnivora			5			X		High-scale
Puma	*Puma concolor*	Least concern	6			X		High-scale
Red fox	*Vulpes vulpes*	Least concern	1	X				Low-scale
Scandinavian wolverine	*Gulo gulo*	Least concern	3		X			Moderate-scale
Serval	*Leptailurus serval*	Least concern	4		X			Moderate-scale
Snow leopard	*Panthera uncia*	Endangered	10			X		High-scale
Spotted hyena	*Crocuta crocuta*	Least concern	12			X		High-scale
Sun bear	*Helarctos malayanus*	Vulnerable	1	X				Low-scale
Tiger	*Panthera tigris*	Endangered	17			X		High-scale
Mega-herbivores								
African elephant	*Loxodonta africana*	Vulnerable	31			X		High-scale
Asian elephant	*Elephas maximus*	Endangered	3		X			Moderate-scale
Cape buffalo	*Syncerus caffer*	Least concern	3		X			Moderate-scale
Great Indian one-horned rhino	*Rhinoceros unicornis*	Vulnerable	1	X				Low-scale
Hippopotamus	*Hippopotamus amphibius*	Vulnerable	1	X				Low-scale
Other mammals								
Aardvark	*Orycteropus afer*	Least concern	1	X				Low-scale
African civet	*Civettictis civetta*	Least concern	2		X			Moderate-scale
Bush pig	*Potamochoerus larvatus*	Least concern	5			X		High-scale
Common genet	*Genetta genetta*	Least concern	1	X				Low-scale
European Bison	*Bison bonasus*	Vulnerable	1	X				Low-scale
European rabbit	*Oryctolagus cuniculus*	Near threatened	1	X				Low-scale
Feral Domestic pig	*Sus domesticus*	Least concern	1	X				Low-scale
Feral house mouse	*Mus musculus*	Least concern	2		X			Moderate-scale
Honey badger	*Mellivora* spp.	Least concern	3		X			Moderate-scale
Mongoose	*Herpestes* sp.		1	X				Low-scale
Rodents	Rodentia	Least concern	3		X			Moderate-scale
Porcupine	Hystricidae	Least concern	5			X		High-scale
Rice field rat	*Rattus argentiventer*	Least concern	2		X			Moderate-scale
Rodent	Rodentia	Least concern	1	X				Low-scale
Squirrel	Sciuridae	Least concern	1	X				Low-scale
Sulawesi warty pig	*Sus celebensis*	Near threatened	1	X				Low-scale
Warthog	*Phacochoerus* spp.		4		X			Moderate-scale
Wild boar	*Sus scrofa*	Least concern	8			X		High-scale

Common name of problem animal	Species	IUCN status	Number of publications	Vulnerability index				Conflict status
				PR	MP	SP	RR/ FR	
Primates								
Agile mangabey	*Cercocebus agilis*	Least concern	1	X				Low-scale
Black and white colobus monkey	*Colobus* sp.	Endangered	1	X				Low-scale
Black howler monkey	*Alouatta caraya*	Least concern	1	X				Low-scale
Blue monkey	*Cercopithecus mitis*	Least concern	2		X			Moderate-scale
Boutourlini's blue monkey	*Cercopithecus mitis* ssp. *boutourlinii*	Vulnerable	1	X				Low-scale
Buton macaque	*Macaca* sp.	Vulnerable	1	X				Low-scale
Chacma baboon	*Papio ursinus*	Least concern	2		X			Moderate-scale
Chimpanzee	*Pan troglodytes*	Endangered	5			X		High-scale
Grey-cheeked mangebey	*Lophocebus albigena*	Least concern	1	X				Low-scale
Kipunji forest monkey	*Rungwecebus kipunji*	Critically endangered	1	X				Low-scale
Long-tailed macaque	*Macaca fascicularis*	Least concern	1	X				Low-scale
Moloney's white-collared monkey	*Cercopithecus mitis* ssp. *moloneyi*	Least concern	1	X				Low-scale
Moustached guenon	*Cercopithecus cephus*	Least concern	1	X				Low-scale
Northern muriqui (woolly spider monkey)	*Brachyteles hypoxanthus*	Critically endangered	**0**				**X**	**Status unknown**
Olive baboon	*Papio anubis*	Least concern	11			X		High-scale
Orangutan	*Pongo* spp.	Critically endangered	6			X		High-scale
Patas monkey	*Erythrocebus patas*	Least concern	1	X				Low-scale
Pig-tailed macaque	*Macaca leonina*	Vulnerable	1	X				Low-scale
Red colobus monkey	*Procolobus* sp.		1	X				Low-scale
Red-tailed monkey	*Cercopithecus ascanius*	Least concern	6			X		High-scale
Rhesus macaque	*Macaca mulatta*	Least concern	2		X			Moderate-scale
Sclater's monkey	*Cercopithecus sclateri*	Vulnerable	1	X				Low-scale
Thomas' leaf monkey	*Presbytis thomasi*	Vulnerable	1	X				Low-scale
Vervet monkey	*Chlorocebus pygerythrus*	Least concern	5			X		High-scale
Yellow baboon	*Papio cynocephalus*	Least concern	3		X			Moderate-scale

Feeding behaviour and depredation diet

Overall, carnivores were the dominant feeding group associated with depredation compared with all other feeding habits, followed by bulk feeders and herbivores (jointly) and then omnivores (Table 6). The following categories of damage occurred (Table 7): crop-raiding only; livestock-depredation only; poultry depredation only; crop-human combined depredation; crop-livestock combined depredation; crop-livestock-human combined depredation; equid-human-livestock combined depredation; equid-livestock combined

depredation; game-human-livestock combined depredation; game-livestock combined depredation; human-livestock combined depredation; and livestock-poultry combined depredation. In most cases, we could not assess the species of crop and livestock damaged through depredation due to a lack of detail reported in the literature. These deficiencies or inconsistencies in reporting prevented a livestock or crop species-level assessment of damage.

Table 6. Generalised linear mixed model showing the dominant feeding habit associated with depredation through pair-wise comparisons. Model degrees of freedom, df=54.

Comparisons	**Dominant feeding habit associated with depredation**	**Std. Error**	**Z value**	***P***
Bulk feeder vs Bulk grazer	Bulk feeder	0.52	-4.08	< 0.001
Bulk feeder vs Carnivore	Carnivore	0.19	8.71	< 0.001
Bulk feeder vs Herbivore	Bulk feeder	0.41	-3.84	< 0.001
Bulk feeder vs Omnivore	Omnivore	0.20	4.15	< 0.001
Bulk grazer vs Carnivore	Carnivore	0.50	-7.50	< 0.001
Bulk grazer vs Herbivore	Similar	0.62	-0.90	0.370
Bulk grazer vs Omnivore	Omnivore	0.51	-5.87	< 0.001
Carnivore vs Herbivore	Carnivore	0.38	-8.38	< 0.001
Carnivore vs Omnivore	Carnivore	0.13	-5.77	< 0.001
Herbivore vs Omnivore	Omnivore	0.39	6.20	< 0.001

Two categories of depredation, namely ‘crop-raiding’ damage and ‘livestock only’ damage dominated over all other types of depredation (Table 7), accounting for the greatest number of HWC incidences.

Table 7. Statistical comparison between categories of depredation exhibited by damage-causing wildlife. Model degrees of freedom, df=47.

Comparisons	Greater impacted variable	Std. Error	Z value	*P*
Crop-raiding vs Crop-Human	Crop-raiding	0.42	-6.36	< 0.001
Crop-raiding vs Crop-Livestock	Crop-raiding	0.35	-6.51	< 0.001
Crop-raiding vs Crop-Livestock-Human	Crop-raiding	0.58	-5.76	< 0.001
Crop-raiding vs Crop-Equid-Human-Livestock	Crop-raiding	1.00	-4.46	< 0.001
Crop-raiding vs Equid-Livestock	Crop-raiding	1.00	-4.46	< 0.001
Crop-raiding vs Game-Human-Livestock	Crop-raiding	0.39	-6.44	< 0.001
Crop-raiding vs Game-Livestock	Crop-raiding	0.28	-6.31	< 0.001
Crop-raiding vs Human-Livestock	Crop-raiding	0.23	-5.70	< 0.001
Crop-raiding vs Livestock	Similar	0.14	1.84	0.070
Crop-raiding vs Livestock-Poultry	Crop-raiding	0.22	-5.24	< 0.001
Crop-raiding vs Poultry	Crop-raiding	0.58	-5.76	< 0.001
Livestock vs Crop-Human	Livestock	0.42	-7.04	< 0.001
Livestock vs Crop-Livestock	Livestock	0.35	-7.33	< 0.001
Livestock vs Crop-Livestock-Human	Livestock	0.58	-6.23	< 0.001
Livestock vs Crop-Equid-Human-Livestock	Livestock	1.00	-4.73	< 0.001
Livestock vs Equid-Livestock	Livestock	1.00	-4.73	< 0.001
Livestock vs Game-Human-Livestock	Livestock	0.39	-7.17	< 0.001
Livestock vs Game-Livestock	Livestock	0.27	-7.38	< 0.001
Livestock vs Human-Livestock	Livestock	0.23	-6.99	< 0.001
Livestock vs Livestock-Poultry	Livestock	0.21	-6.64	< 0.001
Livestock vs Poultry	Livestock	0.58	-6.23	< 0.001

Discussion

Vulnerability of people affected by human-wildlife conflict

Local communities (i.e. people that might or might not farm) were affected by 49 different species of wildlife globally, lending support that such communities are potentially the most common target for a wide range of damage-causing wildlife. This was followed by subsistence farmers and then commercial farmers, indicating that local communities and subsistence farmers reported the most incidents of HWC. These results were consistent with numerous other studies (Hill 2000; Siex and Struhsaker, 1999) that suggest the susceptibility of local and subsistence communities to HWC. The findings concerning local communities also imply that HWC undermines household food security, especially in developing countries where farming operations are marginal and plagued by environmental crises such as desertification and drought (Thornton et al., 2011; UNDP, 2008). Therefore, the effects of

HWC will particularly amplify human hunger and malnourishment rates, typical of developing countries (World Bank, 2013) that house millions of local communities on PA boundaries.

Despite local communities reportedly incurring the highest levels of HWC, our study does not support our prediction that subsistence farmers would experience a higher number of depredation incidences than commercial farmers. However, these findings could be attributed to a greater research focus of HWC in literature devoted to commercial farming industries. It is also possible that these findings were driven by a confounding factor where HWC damage was reportedly higher in local communities because there were many people available to report it, rather than because they actually experience more damage. In our study, local communities and commercial farmers experienced the highest numbers of HWC cases, which were dominated by high-scale conflict species. Our analyses of the literature did not yield any findings where scholars directly compared the impact of DCAs on subsistence and commercial farmers together. Hence, we suggest that a meticulous investigation and comparison is required on how subsistence and commercial farmers co-existing in the same geographic area are impacted by and react to HWC.

Human-wildlife conflict in South Africa versus global studies

Our findings support the prediction that farmers in developing countries were affected by a wider diversity of DCAs than farmers in developed countries. African and Asian people experienced the highest number of HWC cases with all groups of wildlife investigated in this review compared with the rest of the world. Developing countries contain greater biodiversity, more densely populated wildlife species and potentially more DCAs compared with developed countries (DeGeorges and Reilly, 2008), thus eliciting regular acts of depredation. In addition to problem animal density, other elements that increase the frequency of depredation include the condition of farm fences and the prevalence of deterrents (crop and livestock guards and shepherds; Woodroffe et al., 2005). Such preventative measures are often unaffordable for farmers of developing countries, especially poor subsistence households (Naughton-Treves 2006).

South Africa was ranked as having one of the highest numbers of HWC cases (n = 34) caused by a distinct group of DCAs (especially carnivores, primates and mega-herbivores), when compared with the rest of the world, with the exception of Europe (n = 28) (discussed below). South Africa also houses the third richest biodiversity in the world (DeGeorges and Reilly, 2008) and, therefore, the number of HWC cases documented could correspond to the

species diversity of the region since, species-rich areas could potentially be vulnerable to regular HWC compared with the rest of world.

Similarities between the number of HWC incidences in the literature for South Africa and Europe could potentially be idiosyncratic, with novel research foci that do not extend to other geographic areas, particularly around HWC and commercial farming. Although the numbers of HWC incidences were similar for South Africa and Europe, it does not necessarily imply that this is due to similar wildlife assemblages. We believe that South Africa and Europe have experienced similar research emphasis and reporting rates in scientific journals, particularly for commercial farmers, which seems to be the focus of current South African scholars.

Geographic distribution of human-wildlife conflict studies

Our findings showed a substantial increase in publications of HWC in Africa and Asia since 2001. Similarly, Treves (2006) attributed the growing attention and active research efforts in HWC from 1994 to 2015 as an indicator of how HWC issues have increased and intensified. According to Treves (2006), both scholars and the public have paid more attention to HWC issues during this time period. Interestingly, between 1993 and 1999, Google Scholar returned ~3 100 hits for HWC compared with 8 060 hits between 2000 and 2007 (Treves, 2006). Treves (2006) attributed the growing attention in HWC as an indicator of how contentious and intensely HWC issues have developed. However, it should be noted that our results were extracted from a meta-analysis and were subject to reporting bias. Such biases in the literature include model cases that focus on mammals predominantly. In addition, geographic patterns of HWC studies indicated that some African (including South Africa) and South American countries received increased scientific reporting on HWC from 2000 to 2015 particularly. These emergent geographic patterns of HWC studies correspond to rising efforts by global organizations such as the IUCN to address HWC and the associated challenges facing PA management (Madden, 2004, Treves, 2006). It is likely that in the face of additional crises, such as global warming and food insecurity that contribute towards the intensity of HWC, scholars have identified deficits and urgent needs associated with HWC.

Although European colonisation occurred throughout the world and shaped early conservation ideologies (DeGeorges and Reilly, 2008), apartheid laws were distinct to South Africa and contributed to a first-world/third-world dichotomy within the country (Cock and Fig, 2000; DeGeorges and Reilly, 2008; Khan, 1994). Currently, about 3 million subsistence households (Statistics South Africa, 2011) are contiguous with PAs (Cock and Fig, 2000;

DeGeorges and Reilly, 2008). These communities have been marginalised from PA management by conservation protectionist movements in South Africa (Cock and Fig, 2000; Khan, 1994). Hence, our findings demonstrated that the first-world/third-world dichotomy within South Africa, coupled with the sum of disenfranchisement of rural people (Adams et al., 2004), could potentially intensify HWCs on the edge of PAs. Apartheid and concomitant European ideologies existed in South Africa until at least 1994 (Cock and Fig, 2000; DeGeorges and Reilly, 2008), we speculated that such prejudiced principles continue today in practice but not policy. Therefore, it is plausible that the similar pattern between South Africa and Europe in HWC from 1994 to 2015 reflect idiosyncrasies aligned to European farming practices adopted by South African farmers. The first-world/third world dichotomy within South Africa is a theoretical possibility and requires elucidation, because, according to the findings of the meta-analysis, scholars have focused mostly on the first world commercial farmer.

Vulnerability of conflict species

Our results support the prediction in the literature and those of other studies that carnivores were frequent DCAs and the most high-scale conflict species globally (Inskip and Zimmermann, 2009; Potgieter et al., 2015; Treves and Karanth, 2003; Woodroffe and Frank, 2005). Since high-scale conflict potentially leads to retaliation and contributes to the vulnerability of carnivores (also supported by the vulnerability index developed in our study), carnivores are a severely persecuted guild (Treves and Karanth, 2003).

The leopard *Panthera pardus* was the leading carnivore conflict species, featuring in the highest number of human-carnivore conflict case studies. Leopard exhibit an array of biological and behavioural traits that render them high-impact conflict species (Kissui, 2008; Marker and Dickman, 2005; Woodroffe et al., 2005). This highly adaptable species occupies the broadest geographic range (Kissui, 2008) and is better adapted to utilise human-dominated environments, like farms, than other large predators (Di Minin et al., 2016; Nowell and Jackson, 1996).

The African lion, gray wolf *Canis lupus* and tiger *Panthera tigris* also featured prominently in the literature with the joint second highest number of human-carnivore conflict incidences. Smaller carnivores, such as the serval *Leptailurus serval* and jackal *Canis* spp. showed moderate- to high-scale conflict. Similarly, Treves and Karanth (2003) reported that carnivores (small and large) possess a long-standing history of competition with humans. Since free-ranging, large-bodied carnivores such as the African lion have been extirpated

from farmland in South Africa (Potgieter et al., 2015; Stadler, 2006; Woodroffe and Frank, 2005), they do not account for livestock depredation. In contrast, the leopard *Panthera pardus*, cheetah, caracal *Caracal caracal* and jackal frequently range freely in anthropogenic-dominated landscapes (Avenant and Du Plessis, 2008; Marker and Dickman, 2005; Di Minin et al., 2016; Nowell and Jackson, 1996) and were the leading depredators of small-medium livestock in southern Africa (Avenant and Du Plessis, 2008; Marker and Dickman, 2005).

Consistent with our predictions that primates would cause high-scale conflicts due to their ability to transgress PA boundaries, five different primate species appeared in ≥ five published papers in the literature. The results also demonstrated that a wide diversity of primate species showed moderate and low conflict with humans globally. Previous studies depicted baboons *Papio* spp. as exceptional examples that cause extensive damage to crops in Uganda and Ethiopia, and they were perceived by subsistence farmers as the greatest threats to crop yields (Hill, 2000; Quirin and Dixon, 2012). Our findings that a large number of primate species were main DCAs are consistent with that of Estrada et al., (2012) who showed that globally, agricultural landscapes such as orchards, crop farms and forestry plantations were raided by approximately 57 different primate taxa in agro-ecosystems in which PAs and forestry or fruit plantations are contiguous. High levels of forest fragmentation and agricultural infringement were implicated as the cause of human-primate conflict (Estrada et al., 2012). The ability of primates to adapt to anthropogenic-dominated agricultural ecosystems and their often overlapping diets with humans brings them into conflict with farmers (Bracebridge et al., 2013; Estrada et al., 2012). Additionally, our findings that primates and carnivores were high-scale conflict species, concur with several other studies (Inskip and Zimmermann, 2009; Macdonald et al., 2012; Treves and Karanth, 2003; Woodroffe and Frank, 2005), that the threats facing felids, canids and primates are often identical and occur in the same region (Macdonald et al., 2012).

A large number of near-threatened to endangered carnivores, two mega-herbivores (vulnerable African elephant and endangered Asian elephant) and one primate species, the critically endangered orangutan, showed high-scale conflict with humans. These species are an IUCN conservation priority, which coupled with HWC, could exacerbate their extinction risk. In addition, HWC poses serious threats and challenges to conserve these species outside PAs (Treves and Karanth, 2003).

Notably, of the 17 cases where 14 different types of birds featured as the main DCA, the scientific name of only two species were reported (i.e. the blackbird *Turdus merula* and

greater flamingo *Phoenicopterus roseus*). Although vultures were implicated in one case study, only the family name was reported, making it difficult to gauge whether vulnerable or threatened species were involved.

Feeding behaviour and depredation diet

Overall, carnivores were the dominant feeding group associated with depredation when compared to all groups. Previous studies have shown that carnivores were prone to conflicts due to their large home ranges that overlap onto farmland and predation of livestock (Linnell et al., 2001; Patterson et al., 2004). Human-carnivore-conflict is likely to occur in areas in which the natural habitats of carnivores have been transformed into farmland and indigenous, natural prey species have been displaced by domestic livestock (Patterson et al., 2004). The behaviour of some carnivores, for example spotted hyenas *Crocuta crocuta* that feed nocturnally and opportunistically, enables them to exploit human-dominated environments (Holmern et al., 2007).

Interestingly, crop-raiding and livestock depredation jointly accounted for the greatest portion of HWC damage. Although carnivores were the main DCAs implicated in the literature, a large number of primate species also featured prominently in our findings. Hence, carnivores and primates could be the joint leading depredators responsible for HWC-related damage. Several other studies mention crop-raiding as a major problem throughout developing continents, such as Africa and Asia (Hill, 2000; Naughton-Treves, 1998; Siex and Struhsaker, 1999). In Uganda, the most prominent wildlife crop-raiders were African elephant *Loxodonta africana*, bushpig *Potamochoerus* sp., chimpanzee *Pan troglodytes*, olive baboon *Papio anubis* and red-tailed monkey *Cercopithecus ascanius* (Naughton-Treves (1998). All five of these species categorised as high-scale-severely-persecuted conflict species in our analyses. Livestock damage as a leading category of depredation bears serious ramifications for livestock farmers (Holmern et al., 2007; Wang and Macdonald, 2006) and food security since livestock provides an important source of nutrition (FAO, 2015) and income (Sharma et al., 2015) globally.

Conclusions

We acknowledge that the data set may be biased towards English-speaking countries in addition to literature that uses specific terminology and not necessarily a representation of

countries that applied uncharacteristic keywords and phrases. Nevertheless, this study showed that there were parallels and variations among HWC patterns worldwide. Developed countries were characterised by fewer incidences of reported HWC and a contracted diversity of DCAs, whereas developing countries exhibited the highest incidences of HWC, between local communities and a comprehensive diversity of mammals. South Africa, with its distinctive blend of first- and third-world practices, provides a regional exemplar of global trends in HWC. We showed that carnivores and primates were prone to high-scale conflict globally, and that they might engender conservation concern due to retaliation and retribution by people.

Our foundational research has provided the first global assessment of HWC. Although in-depth information concerning the identification, location and feeding behaviour of problem species was derived from the review, gaps in the literature were apparent. The bias in reporting for larger mammal and bird requires elucidation through further research to account for the nature of the involvement of taxonomic groups. Reports concerning retaliatory practices and the occurrence of lethal control of problem species were deficient or omitted in many case studies. Lethal measures will severely affect species of conservation concern. Systematic and in-depth examinations of the most vulnerable groups of people, identified here as local and subsistence farming communities bordering PAs, should be the focus of future HWC research avenues to assess food insecurity that exacerbate malnutrition on the one hand and vulnerabilities of wildlife through retaliation on the other hand.

Glossary of terms

Apartheid. An official government policy of racial segregation formerly practised in South Africa, involving economic, legal and political discrimination against non-white individuals into second-class citizens who were restricted geographically, educationally, socially and professionally (Khan, 1994).

Commercial farmer. Literature regarding a farmer or enterprise that cultivates crops or produces livestock or game for sale with the objective of making a profit (FAO, 2015).

Conflict profile. A measure of the vulnerability of people and farming commodities to human-wildlife conflict based on the number of HWC cases reported in the published literature for such groups of people, in combination with the number of low-, moderate- or high-scale conflict species that commonly affect such groups of people.

Crop-raiding. The feeding or destruction of cultivated food by wild mammals and/or birds that causes significant loss of food and income to farmers (Woodroffe et al., 2005).

Damage-causing animal (DCA). A wild mammal or bird for which there is considerable proof that it causes loss to livestock or game; or causes excessive damage to cultivated crops or poses a threat to human safety (Woodroffe et al., 2005).

Depredation. The consumption of agricultural resources (crops, livestock and game) by wild mammals and/or birds (Woodroffe et al., 2005).

Developed (first world) country. An industrialised country with a well-developed economy and an advanced technological infrastructure relative to other less industrialised countries (FAO, 2015; World Bank, 2013).

Developing (third world) country. A nation with an underdeveloped industrial base that is characterised by people with reduced life expectancy and lower income when compared with developed nations (FAO, 2015; World Bank, 2013).

Edge. A boundary or interface between a protected area and a landscape element (human settlement or farmland) (Woodroffe and Ginsberg, 1998).

Food security. The state in which all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life (FAO, 2015).

Gross Domestic Product (GDP). A nation's total annual fiscal activity (or the monetary value of all the finished goods and services generated within a nation's geographic boundaries (World Bank, 2013).

High-scale conflict species. Wild mammals or birds that frequently (appear in five or more scientific papers according to Inskip and Zimmermann (2009)) attack people and/or recurrently depredate livestock or crops, resulting in frequent retaliatory killings.

HWC hot spot. A biogeographic region in which significantly high incidences of human-wildlife conflict occur (Woodroffe et al., 2005).

Local community. People living adjacent to protected areas or reserves, who may or may not subsist through farming (Anthony, 2007).

Low-scale conflict species. Wild mammals or birds that rarely (appear at least once in a scientific publication according to Inskip and Zimmermann (2009)) attack people, seldom depredate livestock or crops and rarely experience retaliatory killings.

Moderate-scale conflict species. Wild mammals or birds that rarely (appear in two to four scientific papers according to Inskip and Zimmermann (2009)) attack people but may frequently depredate livestock or crops and experience frequent retaliatory killings.

Problem animal. A free-living, native wild mammal or bird whose natural behaviour, temperament or habits brings it into conflict with humans (Woodroffe et al., 2005).

Protected area (PA). A biodiversity conservation area that receives protection due to the presence of indigenous wild fauna and flora that offers great ecological value (Gittleman et al., 2001).

Subsistence farmer. A farmer whose products are intended to provide for the basic needs of the farmer and his/her family with little surplus for marketing, bringing no profit (i.e. allowing for only a marginal livelihood) (FAO, 2015).

Wildlife. This study considered undomesticated terrestrial vertebrate and invertebrate animals.

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Supplementary material

Table S1. Description of categories that gauge vulnerability of human-wildlife-conflict species and severity of conflict. A description of how species were categorised for vulnerability and conflict status is provided using guidelines proposed by Gittleman et al., (2001) and Inskip and Zimmermann (2009). These categories identified levels of biodiversity extinction vulnerability with corresponding abbreviations for such classification.

Category	Description	Category	Description
Index of vulnerability		**Conflict status**	
Poorly researched, data deficient (PR)	Animal appears only once in the database	Low-scale conflict (LSC)	Wild animal rarely attacks people, seldom depredates livestock or crops, rarely experiences retaliatory killing
Moderately persecuted (MP)	Animal appears two to four times in the database and may be moderately persecuted	Moderate-scale conflict (MSC)	Wild animal rarely attacks people, or may frequently depredate livestock or crops, or experiences frequent retaliatory killings
Severely persecuted (SP)	Animal appears more than four times in the database and may be severely persecuted	High-scale conflict (HSC)	Wild animal frequently attacks people and/or recurrently depredates livestock or crops, experiences frequent retaliatory killings
Research required (RR) or Future research (FR)	No research has been conducted on this species	Status unknown (SU)	Anecdotal evidence of conflict is available. No scientific evidence in literature

Table S2. Problem animals that affected commercial farmers, local communities, subsistence farmers and pooled-farmers (subsistence and commercial farmers). Numbers denote the number of cases that appeared in the literature database.

Commercial farmers	Local communities	Subsistence farmers	Subsistence and commercial farmers
Antelopes			
	Kudu (1)	Eland (1)	Musk deer (1)
	Nilgai (1)	Kudu (1)	
	Ungulates non-specific (1)	Nilgai (1)	
		Roan antelope (1)	
		Sitatunga (1)	
Birds			
Birds non-specific (8)	Birds (4)	Raptor (1)	Birds non-specific (1)
Flamingo (1 case)	Raptor (1)		
	Vulture (1)		
Carnivores			
African lion (6)	African lion (7)	African civet (2)	African lion (4)
African wild dog (6)	African wild dog (6)	African lion (4)	African wild dog (2)
American black bear (1)	Amur tiger (1)	African wild cat (1)	American black bear (2)
Brown bear (4)	Asiatic black bear (2)	Cheetah (1)	Brown bear (1)
Caracal (4)	Asiatic jackal (2)	Eurasian lynx (1)	Carnivora non-specific (1)
Carnivora non-specific (1)	Brown bear (2)	Genet (1)	Hyaena (1)
Cheetah (8)	Carnivora non-specific (5)	Hyaena (2)	Jaguar (2)
Coyote (1)	Cheetah (1)	Jackal (1)	Leopard (1)
Eurasian lynx (3)	Eurasian lynx (1)	Leopard (5)	Puma (1)
Hyaena (11)	Florida black bear (1)	Serval (1)	Snow leopard (3)
Iberian lynx (1)	Himalayan black bear (2)	Snow leopard (1)	Tiger (2)
Jackal (7)	Hyaena (3)	Tiger (2)	Wolf (1)
Jaguar (2)	Jackal (2)	Wolf (1)	
Leopard (9)	Jaguar (1)		
Puma (5)	Leopard (10)		
Serval (2)	Red fox (1)		
Snow leopard (1)	Serval (1)		
Wolf (11)	Snow leopard (5)		
Wolverine (3)	Sun bear (1)		
	Tiger (13)		
	Wolf (5)		
Mega-herbivores			
Buffalo (1)	Asian elephant (1)	Asian elephant (2)	Elephant (3)
Bushpig (2)	One-horned Rhinoceros (1)	Buffalo (2)	
Elephant (9)	Rhinoceros (1)	Elephant (8)	
Porcupine (1)			
Wild boar (1)			

Other mammals/Omnivorous feeders			
Commercial farmers	**Local communities**	**Subsistence farmers**	**Subsistence and commercial farmers**
Feral house mouse (2)	Bushpig (2)	Bushpig (1)	Dhole (1)
	Dhole (3)	Feral domestic pig (1)	Porcupine (1)
	European bison (1)	Honey badger (1)	Wild boar (1)
	European rabbit (1)	Mongoose (1)	
	Porcupine (1)	Porcupine (2)	
	Rodents (3)	Squirrel (1)	
	Warthog (2)	Sulawesi warty pig (1)	
	Wild boar (4)	Warthog (1)	
		Wild boar (2)	
Primates			
Baboon (2)	Baboon (9)	Agile mangabey (1)	Baboon (1)
Chimpanzee (1)	Black and white colobus monkey (1)	Baboon (4)	Chimpanzee (1)
Long-tailed macaque (1)	Black howler monkey (1)	Blue monkey (1)	Primates non-specific (1)
Orangutan (2)	Blue monkey (2)	Buton macaque (1)	Sclater's monkey (1)
Red colobus monkey (1)	Chimpanzee (1)	Chimpanzee (2)	Vervet monkey (1)
Red-tailed monkey (2)	Other Primates (2)	Kipunji forest monkey (1)	
Thomas' leaf monkey (1)	Patas monkey (1)	Red-tailed monkey (1)	
Vervet monkey (1)	Red-tailed monkey (2)	Rhesus macaque (2)	
	Vervet monkey (3)	White-collared monkey (1)	

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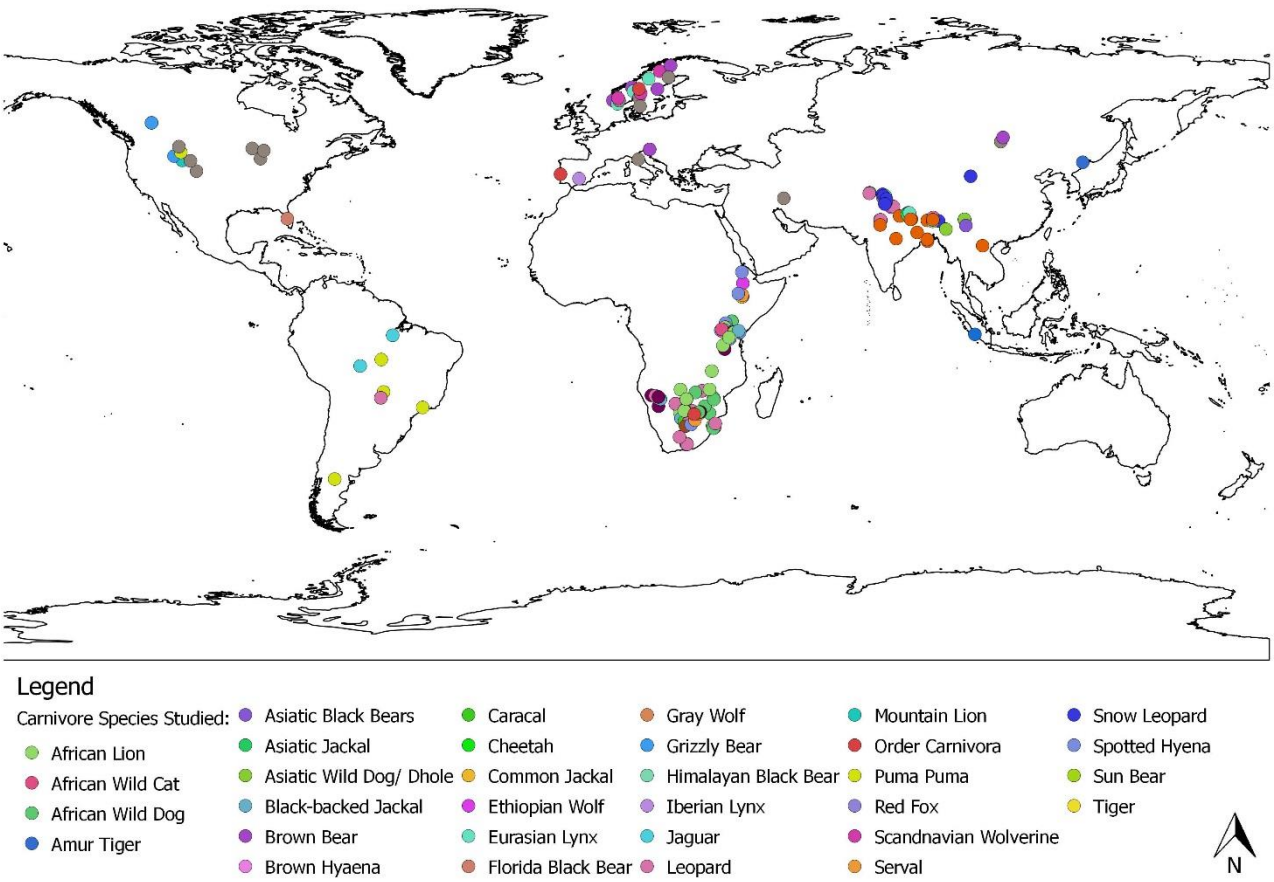


Figure S1. A species-level occurrence of published human-carnivore-conflict from 1994−2015. Coloured circles are global positioning system data points that show human-carnivore-conflict study sites by species.

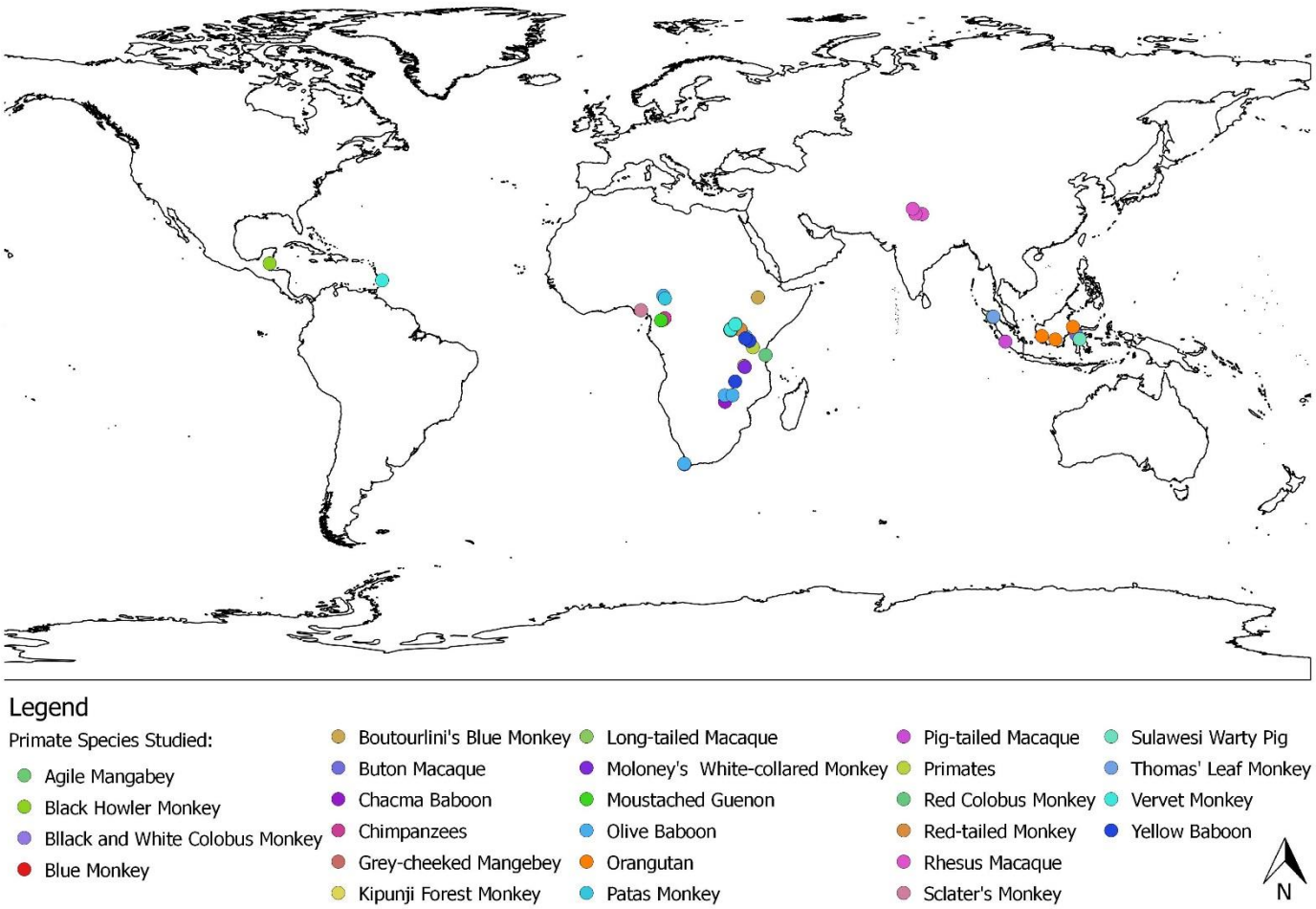
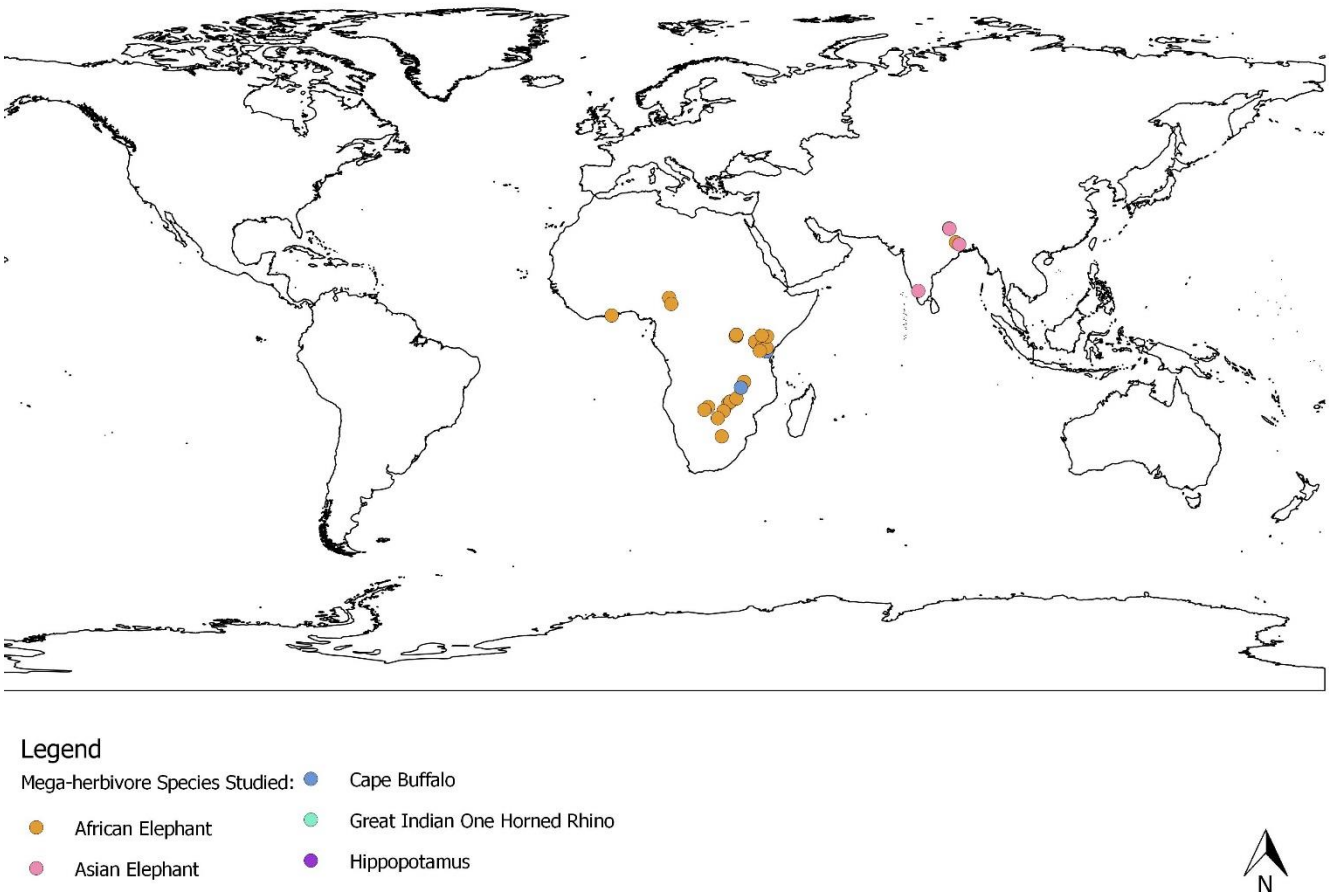


Figure S2. A species-level occurrence of published human-primate conflict from 1994−2015. Coloured circles are global positioning system data points that show human-primate-conflict study sites by species.



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2340 **Figure S3.** A species-level occurrence of published human-mega-herbivore conflict from 1994
2341 −2015. Coloured circles are global positioning system data points that show human-mega-
2342 herbivore-conflict study sites.
2343

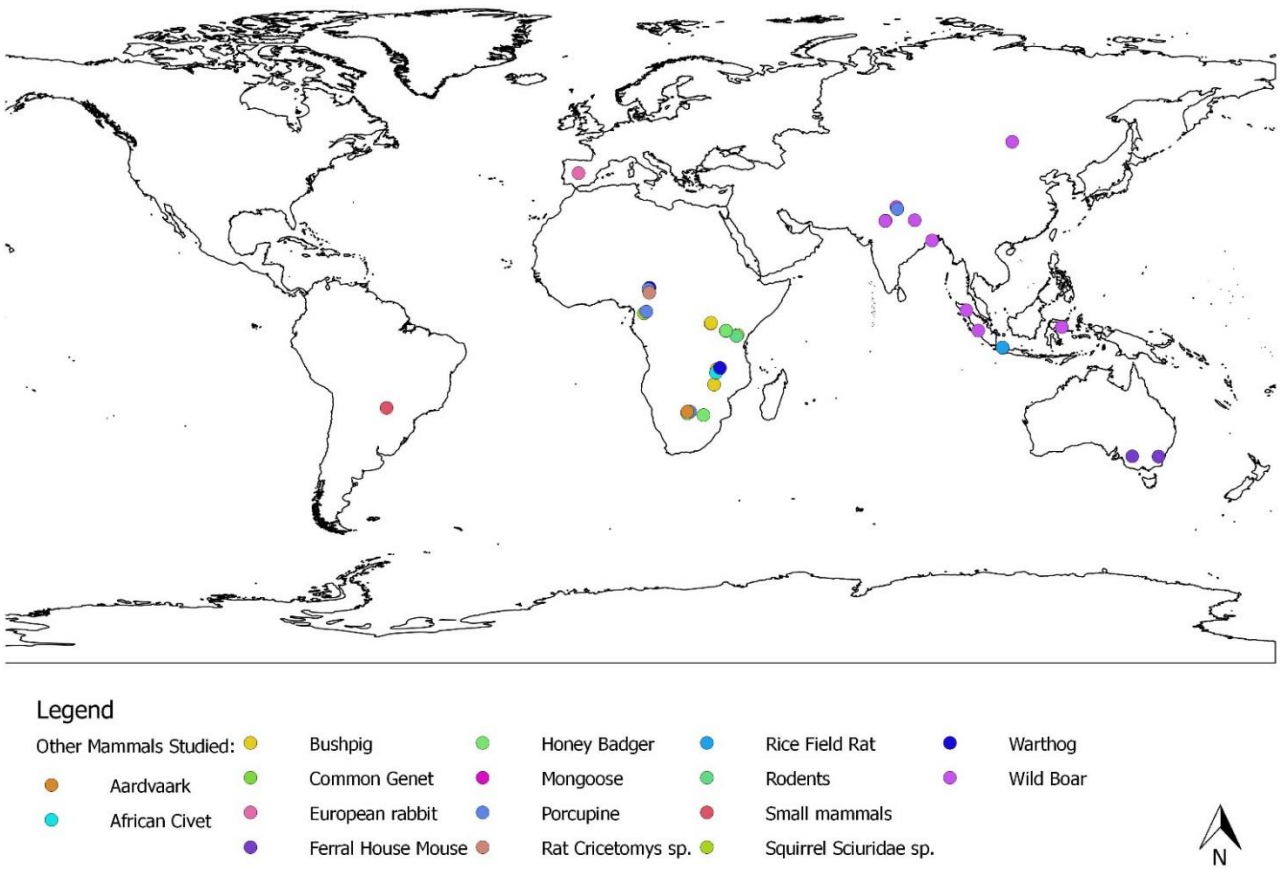


Figure S4. A species-level occurrence of published human and other mammal conflict from 1994 − 2015. Coloured circles are global positioning system data points that show human-other-mammal-conflict study sites by species.

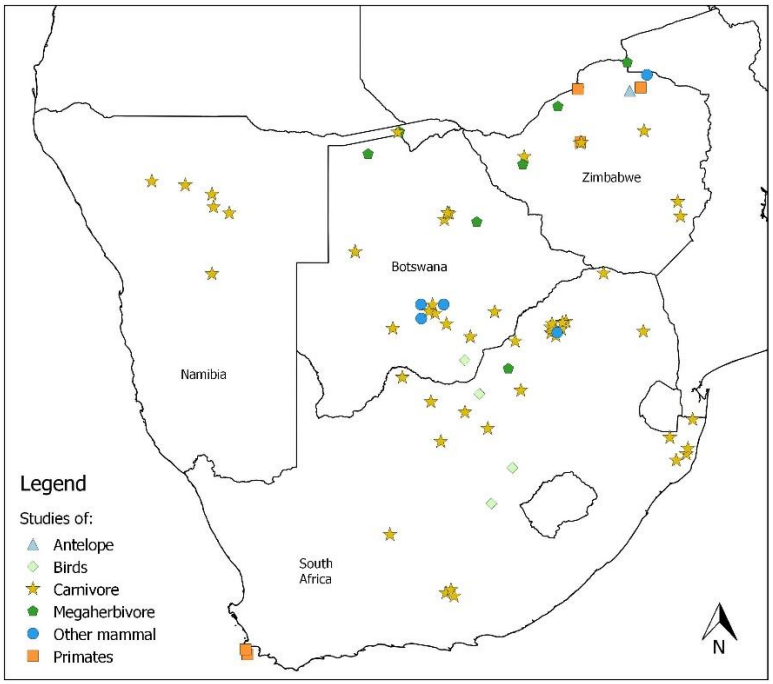


Figure S5. The distribution of publications concerning human-wildlife conflict in Sub-Saharan Africa from 1994−2015. Coloured circles are global positioning system data points for wildlife involved in human-wildlife conflict.

CHAPTER THREE

General methods

Section A: Farmer survey

Materials and methods

Study sites

This study took place at selected localities within the provinces of KwaZulu-Natal, Mpumalanga and Limpopo in South Africa (Fig. 1; Table 1) where conflict between farmers and wildlife was most likely to occur due to the proximity of agricultural and conservation areas (**Supplementary material:** Figs. S1-S2) (Naughton-Treves, 1999). Specifically, all sample sites included farms, homesteads and residential homes located adjacent to or near protected areas (PAs) (game reserves, nature reserves, local game parks or national game parks) and situated within less than 1 m and up to 5 km from the PA boundary, depending on the location and access to the site. Commercial farms within close proximity to subsistence rural settlements (within a 5 km radius) were visited during field expeditions. In total, 249 farmer surveys were conducted (n = 115 commercial farmers, n = 134 subsistence farmers) (Table 1).

It is noteworthy that all the farmers interviewed in the Waterberg were located within the Waterberg Biosphere Reserve (-23,16 to 24,66 S; 27,5 to 28,66 E), Limpopo Province, South Africa. The Waterberg is a designated biosphere reserve (a 650 000 ha area set aside to reconcile the conservation of biodiversity and sustainable natural resource use by the United Nations Educational, Scientific and Cultural Organization (UNESCO); Swanepoel et al., 2015; De Klerk, 2003). The Waterberg Biosphere Reserve supports a host of native antelope, giraffe, white rhinoceros and warthog, in addition to free-ranging carnivores, such as leopard and wild dog (Swanepoel et al., 2015; De Klerk, 2003). Notably, the Waterberg Biosphere Reserve, comprises a network of subsistence livestock and crop farms (De Klerk, 2003) commercial crop (De Klerk, 2003) and game-livestock farms (Thorn et al., 2013) within the biosphere reserve, where conflict between carnivores and livestock/game farmers are common (Thorn et al., 2013). In addition, previous studies have shown that a mixture of subsistence pastoralists (Gusset et al., 2008) and crop farmers (Elliott and Steele, 1994) are in conflict with wildlife in KwaZulu-Natal Province, South Africa. In addition, both commercial

and subsistence livestock farmers in KwaZulu-Natal have expressed concerns over damages caused by livestock depredators (Whittington-Jones 2012). All study sites were contiguous with protected areas with abundant wildlife and were therefore suitable to assess human-wildlife conflict in these sites.

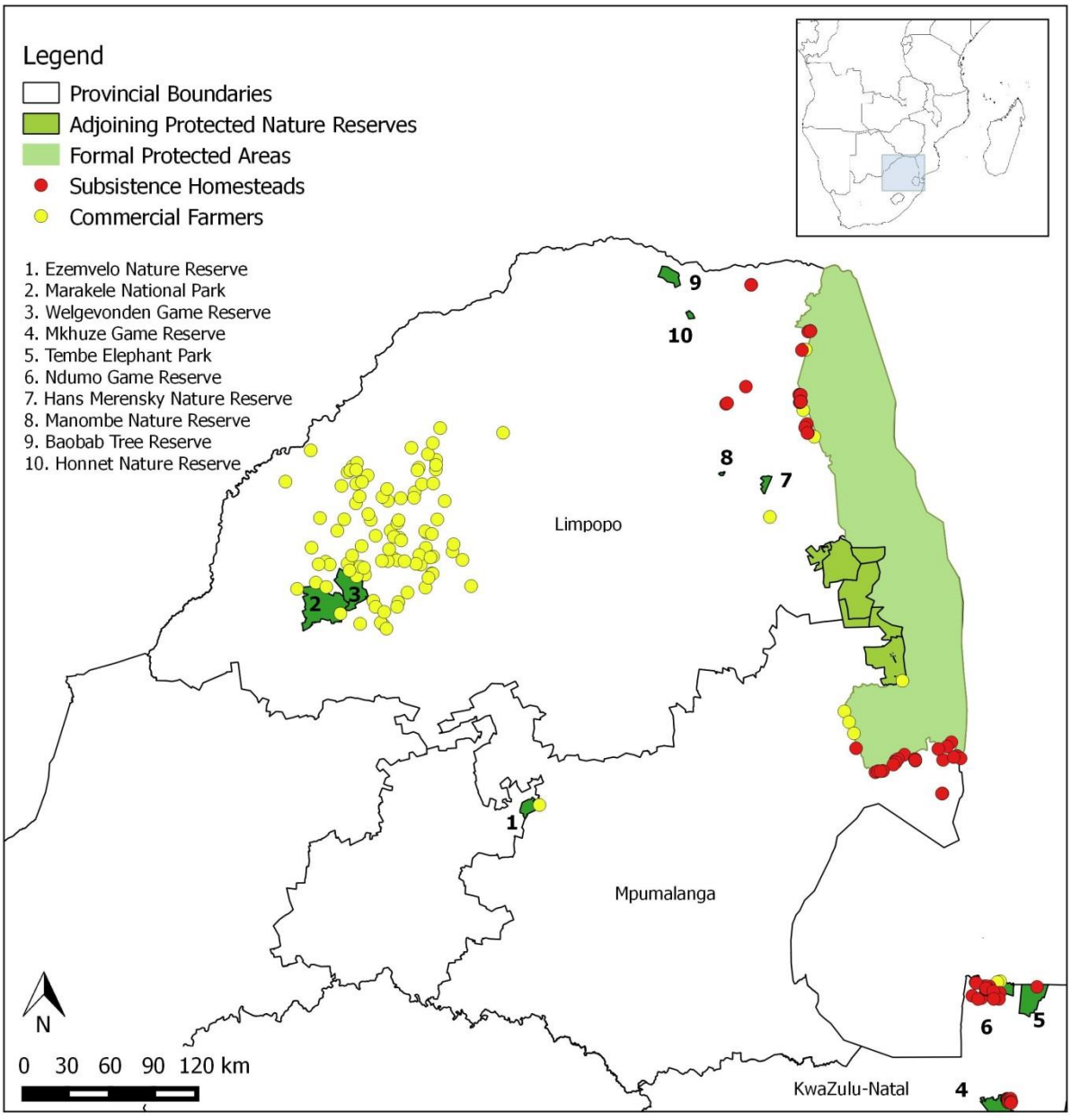


Figure 1. Location of subsistence farmers and commercial farmers surveyed in north-eastern South Africa showing the major protected areas only. Red and yellow circles are global positioning system data points that indicate the location of sampled subsistence and commercial farmers respectively. Other formal protected areas appear in **Supplementary material:** Figs. S1-S2. A map of southern Africa is provided in the inset.

Table 1. Administration of semi-structured farmer interviews, listing the type and number of farmers sampled at each site and the total number of surveys conducted. No subsistence farmers were interviewed/sampled in the Waterberg region and no commercial farmers in Mkuze, because mixed farming practices are atypical of these areas.

Province	Locality (Town or District municipality	Number of surveys per site	Sample size Subsistence farmers	Sample size Commercial farmers
Limpopo	Giyani	41	30	11
	Waterberg	97	0	97
Mpumalanga	Komatipoort	33	28	5
KwaZulu-Natal	Ndumo	54	52	2
	Mkuze	24	24	0
Total farmers sampled		**249**	**134**	**115**

Data collection and sampling procedures

Data collection comprised semi-structured questionnaire interviews and site inspections to verify farm attributes (discussed later). Permission to carry out this research was granted by the Human Ethics Research Committee (HREC), University of the Witwatersrand, under protocol number H120807. The identity of all respondents remained anonymous during this study as outlined in the conditions of the ethics permit. Fieldwork was conducted from August 2012 until December 2014. I gathered signed consent from each respondent to participate in the study prior to conducting each survey. Each survey was conducted at each farm or homestead, after which permission was sought from each respondent to examine various physical elements of the farm or homestead. With a single visit, inspections involved: (i) the measurement of the garden or farm size; (ii) identification of the type of crops and/or livestock and/or poultry farmed; and (iii) inspection of property fences and their condition. Although visits occurred mainly in summer, questions regarding year-round farming activities were posed to respondents. A semi-structured interview does not comprise a rigorous set of questions as in the case of a structured questionnaire but permits the interviewer to divert from a set structure. A semi-structured questionnaire is open, allowing for comments or new ideas to be raised during the interview depending on what the respondent says. However, the interviewer possessed a framework of themes to be investigated in the form of a questionnaire, with informal grouping of topics and questions that enabled the interviewer to focus on the objectives of the research (White et al., 2005).

I used stratified random sampling techniques (Dickman, 2008) to identify the subsistence and commercial farmers for sampling. Stratified sampling ensured that respondents with certain characteristics (e.g. people that engaged in subsistence and

commercial farming) were included in the sample. For this, I first identified people in the population who had the desired characteristics to address my research objectives (subsistence and commercial farmers operating near PAs within the broad study area) and then selected every second homestead or farm that was closest to a PA boundary for one visit only. However, not every household or farm selected by random stratified sampling meant participation in the study. This was either due to their absence or refusal to participate or due to time constraints (a limited number of interviews: approximately five to ten took place per day). Locations of commercial farmers were identified using Google Earth (2012) and Agri SA, (www.agrisa.co.za), a federation of agricultural organisations in South Africa, as well as Wildlife Ranching South Africa (WRSA) (http://www.wrsa.co.za). Locations of rural settlements contiguous to PAs were identified through the Department of Rural Development and Land Reform (2012) and Google Earth (2012).

Interview methods

Respondents were invited either to complete the questionnaire themselves or to participate in the semi-structured interview. Since this study dealt with a diverse group of people with different levels of English proficiency, ranging from no English comprehension to full English comprehension, as well as different levels of education and economic backgrounds, I implemented an approach that enabled the acquisition of data efficiently with the least amount of bias. People with no English comprehension required a translator or interpreter. The semi-structured interview approach provided all respondents with the opportunity to explain their views in their own words and for the interviewer and translator to understand fully the nature and context of a particular situation (Dickman, 2005; Hunter and Brehm, 2003). Disadvantages of semi-structured interviews include time and financial constraints to collect and analyse large amounts of information in this manner. Another shortcoming of semi-structured interviews is biased and prejudiced data being elicited by the vantage point of the interviewer and by the lucidity and articulacy of the respondent (Dickman, 2005; Dickman, 2008; Glastonbury and MacKean, 1991). Particular subjective responses to anticipate, include the exaggeration of losses due to livestock/crop depredation, the overestimation of losses and the tendency to attribute losses to problem animals, even if other factors such as disease, poor soil conditions, low rainfall and theft, were contributors (Rasmussen, 1999). Despite these limitations, in Namibia (Marker et al., 2003; Schumann et al., 2008), Kenya (Sitati et al., 2005), South Africa (Thorn et al., 2013; Thorn et al., 2015) and China (Allendorf et al., 2012), structured questionnaires and semi-structured interviews

have been successfully used to assess the impacts of damage-causing animals (DCAs) on local communities, game and livestock farmers (Dickman, 2005; Dickman, 2008). Some scholars suggest that fostering trust with respondents assisted with eliminating exaggerations and biasness (Dickman, 2005; Dickman, 2008; Glastonbury and MacKean, 1991).

Each household or farm was selected as the sampling unit and visited once only. Interviews were restricted to one respondent per household or farm to avoid pseudo-replication. At each rural community, permission to conduct the survey was sought from the village chief, to whom the purpose of the survey was explained. The head or most senior member present of the subsistence household was invited to participate in the survey and advised that he or she could decline to participate for any reason, withdraw at any stage during the interview process and decline to answer any question, if so wished.

No financial enticements were offered, and interviewers conducted themselves ethically, professionally and with respect. Participants were informed that they might report any complaints to the Human Research (Non-Medical) Ethics Committee or to Professor Neville Pillay, the supervisor of this study at the University of the Witwatersrand, Johannesburg.

All interviewees were adults of 21 years old and older. All interviews were conducted at the respondent's farm or household, and each interview took approximately 30 minutes to complete. Questions that were not answered were classified as no responses.

Capturing and coding of questionnaire data

The questionnaire data were captured by manually entering the paper questionnaire responses onto an electronic data file in Microsoft Excel. The responses were coded by assigning predetermined codes to responses for further processing and analysis. The capturing and coding process required the creation of a worksheet/spreadsheet template. Each interview question was captured on a separate worksheet. The template included the study question with column headings indicating the participant identity number, the actual response and a code for the response. The participant identity number was labelled according to the location of where the survey was conducted and whether the participant was a commercial or subsistence farmer. For example, GIYFC001 referred to an interview conducted in Giyani (GIY) with a commercial farmer (FC), while GIYFS001 referred to an interview conducted in Giyani (GIY) with a subsistence farmer (FS). The goal was to transfer manually all data from questionnaire into a spreadsheet, where each response occupied one cell. If the response was multivalent, responses were split into separate cells in consecutive rows. For example, if a

respondent indicated he/she lost "game", "livestock" and "poultry", each category appeared on a separate row and the participant identity number was repeated for each split for that respondent. I developed and defined a set of coding categories for each question in the survey. This required detailed interrogation of questionnaire transcripts, by reading and re-reading responses to identify and label recurrent words, themes and concepts (Lindsey et al., 2005). A list of the codes was created with a short definition or attribute for each code. Responses were then fitted/slotted into one of the codes within this list (Lindsey et al., 2005, White et al., 2005).

Most of the questions allowed for trichotomous answers, coded as yes, no and no response, or agree, disagree and unsure. The no response was also included to assess the full spectrum of responses of subsistence and commercial farmer so as to foster trust during feedback interviews, as suggested by other scholars (Dickman, 2008; Lindsey et al., 2005). Other coded categories included biographical information. A few questions were open-ended (Lindsey et al., 2005, White et al., 2005) to permit respondents to express their opinions, beliefs and concerns in their own words, the results of which were reported as illustrated quotes (Lindsey et al., 2005) and translated into English, if necessary. The global positioning system (GPS) co ordinates of the respondent's farm were recorded so that the HWC data collected for each questionnaire could be displayed spatially (Fig. 1).

Framework and content of the farmer survey

The framework of the questionnaire was developed in consultation with Dr Michelle Thorn, a researcher from the Endangered Wildlife Trust, who previously piloted similar questionnaires on HWC. Dr Thorn provided advice on several elements of HWC, such as common DCAs, characteristics of commercial farms that potentially affect depredation rates, prevalent retaliatory practices, and factors influencing attitudes and perceptions to wildlife and conservation issues adopted by farmers in South Africa. The questionnaire (Appendix I) was designed to record (and later assess) information regarding characteristics and attributes of the respondent, farm or garden (Chapter 4), characteristics of reported human-wildlife conflict (HWC) incidences, retaliatory or persecution practices (Chapter 5) and attitudes and opinions of farmers towards wildlife (Chapter 6).

The questionnaire was divided into four segments to address the aims and objectives of chapters 4 to 6.

1) *Demographic and socio-economic information* (Chapter 4). A range of demographic variables were collected, including the respondents' age, first/home language,

educational background, tribal group or ethnicity and religious affiliation, as well as the number of people living in the household. Questions also included details concerning household income to place into context the local households' involvement in food security and the relative importance of income from livestock and agriculture to respondents' livelihoods.

2) *Details of livestock depredation or crop raiding incidences* (Chapter 5). Key issues covered during the interviews included details of the species involved in HWC and the number of sightings of potential DCAs on the farm or in the garden. To verify whether subsistence and commercial farmers correctly identified DCAs, they were shown a series of photographs of the chacma baboon *Papio ursinus*, African wild dog *Lycaon pictus*, vervet monkey *Chlorocebus pygerythrus*, leopard *Panthera pardus*, honey badger *Mellivora capensis* and jackal *Canis* spp. Interspersed with the photographs of the aforementioned species, were photographs of exotic animals and animals that are similar in appearance that do not occur in the study area, such as the chimpanzee *Pan troglodytes*, dhole *Cuon alpinus* and jaguar *Panthera onca* (**Supplementary material:** Fig. S3). This approach has been used in previous studies to evaluate the reliability of respondents to recognise local wildlife (Dickman, 2005; Dickman, 2008). In addition, all interviewers were able to correctly identify the species in the photographs, which ensured that correct species were captured. Only correctly identified responses were included in the data analyses. Any scientific terminology used in the questionnaire were explained to the respondents in layman's terms and in their home language if necessary, to ensure that participants understood the question.

In addition, details regarding the approximate dates of such sightings, if repeated sightings of such DCAs occurred and estimates of crop and livestock losses attributed to problem animals (Appendix I) were included. Additionally, methods used to identify problem animals, descriptions of persecutions and use of lethal and non-lethal control methods, were queried (Chapter 5).

3) *Farmstead and ecological information* (Chapter 4). Questions concerning farm and homestead attributes considered the size and proximity of farms to reserve edges, the composition of farm holdings (crop, livestock, poultry, game or mixed farming), whether these farms were fenced off or not, and if so, were the fences wildlife-proof (e.g. electrified). Although several environmental and ecological characteristics were considered by recording their presence or absence on each farm, two physical elements of each farm warranted further inspection due to their importance in predicting HWC: the type of fence present and the site's reliance on irrigation to feed crops and grazing pastures of livestock. Fencing is believed to

be an important tool to keep out wildlife, thus promoting coexistence (Kesch et al., 2015). Poor fence construction and maintenance has been shown to increase incidences of HWC, especially where PAs abut neighbouring communities (Anthony, 2007). Irrigation has been shown to attract wildlife onto farmland and thus increase opportunities for HWC (Thouless and Sakwa, 1995), especially on unfenced farms.

4) *Attitudes and opinions of the subsistence and commercial farmers towards wildlife* (Chapter 6). A list of questions regarding values towards wildlife was posed to interviewees to gauge the attitudes and opinions of farmers, which were subsequently investigated. Specific methods for this segment such as the evaluation of attitudes and the construction of a GIS Threat Index were developed (Chapter 6).

Questionnaire responses regarding farmstead attributes and ecological information were verified by visually inspecting the fences and types of irrigation on the farm. Details concerning the type of crop and vegetable cultivated as well as the composition of livestock, game or poultry were examined. Information regarding crop harvest and lambing or birthing periods were also recorded through the questionnaire to examine the relationships between levels of peak crop or livestock production and conflict (Chapter 5). The questionnaire also requested the respondent to comment on the presence or absence of items in a list of complementary and environmental factors that are critical for farming and that may contribute to agricultural output and livestock production. These questions queried the presence or absence of soil erosion, veld fires, insect pests (on crops and livestock) and frost. Other variables recorded were the presence or absence of disease (fungus on crops or disease of livestock or game) and theft. In this part of the questionnaire, environmental correlates of HWC damage were thus considered.

The data extracted from the questionnaire responses were separated to follow the aims and objectives of the respective chapters and do not follow the sequence of Appendix I.

Section B: Conservation practitioner survey

Materials and methods

This study took place in the same broad geographic region as the farmer survey in Section A, and a detailed map of respondent distribution is provided in Chapter 7. In total, 49 conservation practitioners were sampled (Table 2).

Table 2. The name of the conservation authority with which the conservation practitioners that participated in the study were employed and the number of participating conservation practitioners.

Parks board/authority	Province	Sample size
Limpopo Tourism and Parks Board	Limpopo	17
Mpumalanga Tourism and Parks Agency Board	Mpumalanga	9
Ezemvelo Nature Reserve	Mpumalanga	4
Ndumo Game Reserve and Tembe Elephant Park	KwaZulu-Natal	15
Mkuze Game Reserve	KwaZulu-Natal	2
Phinda Game Reserve	KwaZulu-Natal	2
Total practitioners sampled		**49**

Data collection, interview methods and sampling procedures were identical to those outlined in Section A with a few distinctions that are discussed here. This study examined a variety of factors affecting wildlife monitoring, in addition to assessing the attitudes and opinions of conservation practitioners. Conservation practitioners employed at PAs (individuals involved the management of ecological resources, such as university or technikon trained individuals in the fields of Zoology, Botany, Nature Conservation or Ecotourism Management, and excluded maintenance workers) within the study area were sent electronic invitations to participate in this study through professional societies such as the South African Wildlife Management Association, the Endangered Wildlife Trust and various tertiary institutions. Respondents were invited either to complete the questionnaire themselves or to participate in a semi-structured interview. Anticipated subjective responses from participants included exaggerations of community engagement and understatements of the trans-boundary movement of wildlife (Rasmussen, 1999).

Framework and content of the conservation practitioner survey

The framework of the questionnaire was developed at the outset of this study, in consultation with several conservation authorities from the Endangered Wildlife Trust who provided advice regarding several elements of community conservation. The questionnaire (Appendix II) was designed to gather information regarding characteristics of the respondent and PA attributes. In addition, characteristics of interactions with local human communities, wildlife monitoring and attitudes and opinions of conservation practitioners towards local people and communities were recorded. The questionnaire was divided into four categories to address the aims and objectives of Chapter 7.

1) *Demographic and socio-economic information*. Information using the same categories for demographic information as in the farmer survey was collected.

2) *Protected area and ecological information*. Details concerning the physical attributes of the reserve or PA were considered, such as the size and proximity of the reserve to farms or local communities, whether the reserve was fenced or not, and if so, was the perimeter fence wildlife-proof (i.e. electrified). The questionnaire also requested the respondent to comment on the presence or absence of items in a list of abiotic factors that are indicative of veld condition and carrying capacity of the reserve, such as rainfall, soil quality, disease or parasites, heat stress and tannin toxicity. These abiotic factors could potentially affect forage quality and availability, which has been shown to promote trans-boundary movements of wildlife in search of food and water (Holmern et al., 2007). Another variable investigated was the prevalence of poaching, which could affect attitudes of conservation practitioners towards local people living near PA boundaries.

3) *Details of wildlife diversity and wildlife monitoring*. Information collected included details and numbers of ungulate species stocked and the presence and approximate numbers of potential DCAs. Details regarding the implementation of wildlife- and perimeter-fence monitoring were also considered, as well as the prevalence of specific animal damage-control authorities.

4) *Interactions with farmers and communities*. In this segment of the questionnaire, a variety of interactions between conservation practitioners and local human communities living near PA borders were examined, such as the frequency of communication; the implementation of environmental education and community engagement programmes; and opinions concerning community-based-natural-resource-management (CBNRM). Environmental education (EE) programmes refer to the teaching of local people and communities living contiguous to protected conservation areas about how ecosystems function and how to manage their behaviour to live sustainably, thus enhancing environmental awareness. Community engagement programmes refer to meetings between conservation authorities and local people and communities living near PA boundaries in order for parties to gain knowledge of the natural environment and the hardships faced by the community, to bring awareness to the associated challenges and problems and to engage in solutions to such problems.

The questionnaire requested the respondent to comment on the presence/frequency or absence of these programmes. A list of questions regarding values towards local human

communities around PAs and wildlife was also presented to respondents to gauge the attitudes and opinions of conservation practitioners.

The data extracted from the questionnaire responses were separated to achieve the aims and objectives of Chapter 7 and do not conform to the sequence of Appendix II.

Section C: Data analysis

This study presents both descriptive and quantitative analyses. Descriptive qualitative summaries for reporting statistics concerning language, ethnicity and religion are provided. All quantitative analyses were performed using the statistical software R version 3.1.3 (R Core Team, 2015, https://cran.r-project.org/bin/windows/base/old/3.1.3/). Bar plots were produced through the R software GrapheR extension version 1.9-84 (Hervé, 2011). For all tests, coefficient estimates, including the residual degrees of freedom, standard error, z statistic and corresponding P-values, were generated through a generalised linear mixed model (GLMM) fit by maximum likelihood (with Laplace approximation) for both fixed and random effects using an lme4 extension (Bates et al., 2015) for fitting mixed-effects models.

A GLMM is appropriate to assess the impact of HWC on the two farming groups, because it is an extension to the generalized linear model, containing random effects (e.g. farm location) in addition to the typical fixed effects (e.g. subsistence and commercial farmers). All GLMMs performed were fitted via maximum likelihood, equivalent to the Akaike information criterion (AIC). The GLMM allows the specification of models whose response variable follows non-normal/error distribution (e.g. counts of participants' responses (Poisson) from the questionnaire, which can have many zeros or no responses), or binary distributions (yes/no responses). In addition, the GLMM allowed me to examine differences between and within farms. A Poisson error structure with a log link function was used for count data throughout the GLMM analyses, except for binary data, in which case binomial distribution was used with the log link function, because continuous responses could be exaggerated.

Throughout the thesis, farmer type refers to subsistence and commercial farmers (fixed variables). When examining regional/location variations in farming practices (for example, when subsistence farmers were surveyed in Mkuze) this was factored into the analysis by modifying the R Code (indicated by 1|Loc). In addition, I specified the script family=binomial for the GLMM whenever the response variable was binary. Detailed

information regarding the arrangement and analyses of variables and covariates, used for each experimental chapter is included under specific methodology and data analysis segments within these chapters. Notably, I refer to the following variables as covariates in the thesis: number of respondents experiencing HWC, household size, household income, the number of farms affected by crop raiders or livestock depredators, environmental challenges, presence or absence of irrigation, presence or absence of electrified fencing. Each model was set up according to the fixed and random factors being investigated and the explanatory and response variable was not static or the same for each investigation.

Section D: Geographic information system map constructions

The latitude and longitude co-ordinates of the GPS co-ordinates for each interview were captured separately for importation into Quantum GIS (QGis) 2.8.1 for GIS analysis. The shape files of major national and provincial nature reserves were obtained from the South African National Biodiversity Institute (SANBI), Biodiversity Geographic Information System (BGIS) database (http://bgis.sanbi.org/index.asp?screenwidth=1600). The shape files of PAs were used as a base layer and opened first, onto which interview GPS data points from the questionnaires were overlaid to display HWC spatially in north-eastern South Africa.

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Appendix I – Farmer questionnaire

CONSENT FORM

UNIVERSITY OF WITWATERSRAND

SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCE

PhD STUDY QUESTIONNAIRE CONSENT FORM

Date : _____

Questionnaire Number: _____ **Location:** _____

Hello, my name is Nimmi Pillai and I am a PhD student at the University of the Witwatersrand in Johannesburg. I would like to invite you to participate in my research project about the interactions between farmers and wildlife that live in this area.

This form is to confirm that you have understood what my study is about and that you are willing to participate in it. Either you can sign your consent yourself at the bottom of the form or I can sign that you have given me permission to proceed with the interview that will take no more than 30 minutes.

CONSENT

I hereby agree to participate in the survey study on human-wildlife conflict. I understand that I am participating freely and without being forced in any way to do so. I also understand that I can stop this interview at any point should I want to discontinue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me personally.

I have received the telephone number of a person to contact should I need to speak about any issues, which may arise in this interview.

I understand that my participation will remain confidential.

I understand that if at all possible, feedback will be given to my community on the results of the completed research.

_____ _____

Signature of participant **Date**

Signature of researcher: _____

(This document and the questionnaire will be translated into the first language of the participant if required)

INFORMATION SHEET - FARMER SURVEY

UNIVERSITY OF THE WITWATERSRAND

SCHOOL OF ANIMAL, PLANT & ENVIRONMENTAL SCIENCES

HUMAN-WILDLIFE CONFLICT QUESTIONNAIRE SURVEY

Information Sheet

Hello, my name is Nimmi Pillai, a PhD student at Wits University, and I would like to invite you to participate in a questionnaire survey. In advance, thank you for agreeing to take part in this study- your time is appreciated! If you belong to a rural community then you have been selected as a potential respondent as I am stopping at every second house. If you are a commercial farmer then you have been selected from an agricultural database. Your participation in this survey is completely voluntary and if you choose not to take part, you will not be penalised.

The survey is part of a PhD study at Wits University. I am studying the interactions between farmers and animals. I hope that this survey will do good to your community and help protect wildlife as well.

I want to gather information about your farm/garden, if your crop/stock is damaged by wild animals, how you react to these damages, and how you feel about wild animals. Your answers will help find out when, where and how often this conflict happens and how the people working for Parks can help you. The study will also tell us the cost of this damage and how this may affect food shortage. I will also use this information to find ways to resolve the problem.

I will be asking you some questions about the crops you plant, where you plant them and what problems you may face with how much you are able to produce. I will also be asking some basic questions about the household to gather information about work and income. I will ask questions about your livestock and if you experience any loss of these animals due to wildlife. Lastly, I will ask to see your garden or farm and measure its size, as well as the area of any damages you may have experienced during the growing season.

The survey will take about 30 minutes to complete. Should you wish to complete this survey anonymously, and have the means, please fax the completed questionnaire to 086 653 1404. Great effort will be made to keep your personal information confidential. Contact details are only required so that the research team can give feedback on survey results. The research team may want information for further research studies to see any changes over time. Contact information will only be shared within the research team. Your responses cannot be associated with your identify. If you feel uncomfortable at any stage you may stop and this will not be a problem.

If you have any further questions about the project please feel free to contact my supervisor, Professor Neville Pillay on (011) 717 6459; Neville.Pillay@wits.ac.za or you may call me on 072 2381404. You may also report any complaints to the Human Research Ethics Committee at the University of Witwatersrand, Johannesburg.

Thank you very much for your help and time.

Nimmi Seoraj-Pillai

QUESTIONNAIRE - FARMER SURVEY

Please answer where applicable

FARMER'S SURVEY

Interviewer(s): _____ **Date:** _____

Interviewee:

Title _____ First name _____ Surname _____

Participant information

1. What is the main use of your farm/garden? ☐ (Commercial) / sell your crop/livestock

☐ (Subsistence) / Food for your family ☐Leisure

2. Position: ☐Head of household ☐ Owner ☐ Manager ☐ Employee

☐ Other (please specify) _____

3. Village/ Farm name: _____4. Farm Number: _____

5. What is your first language? _____

6. Postal/Email address: _____

7. Contact number: _____

8. Do you live at your village/ farm? ☐ Yes ☐ No

9. How long have you owned/worked at the village/ site: _____years _____months

10. What tribal group or ethnicity do you belong to?

_____ ☐ No response

11. What religion do you practice?

_____ ☐ No response

12. What is your highest level of education? _____

13. If you are not the head of the household, please state the a) age b) gender and c) highest level of education for the head of this household:

a) _____ b) _____ c) _____

14. What is the total household income per month?

☐ < R500 ☐ R500- R1000 ☐ R1000- R5000 ☐R5000- R10 000 ☐>R10 000

☐ No response

15. How many people live at this household? _____

Farm attributes

16. How large is your farm/garden: _____m x m

17. Does your village/farm border a game park or protected area? ☐ Yes ☐ No

18. If yes, how often do you talk to or get communication from the conservation staff that work there?

_____

19. Do you have a fence around your farm/garden? ☐ Yes ☐ No

20. Is your fence wildlife-proof? ☐ Yes ☐ No

21. Which crop/animal do you farm with?

☐ Livestock ☐ Game ☐ Maize ☐ Wheat

☐ Vegetable (Tomatoes/ potatoes) ☐ Homestead garden

☐ Other (specify): _____

22. If you plant crops, when do you harvest your crops? _____

23. If you farm with livestock/game, what time(s) of year are the lambs born? _____

_____

24. Do you use artificial irrigation or do you rely on rainfall?

_____

25. Do you have any of the following problems on your village/ farm?

☐ Flooding ☐ Bad sandy soil ☐ Soil erosion ☐ Veld fires

☐ Disease/ parasites ☐ Insect pests ☐ Fungus on crops ☐ Theft

☐ Frost ☐ No problems ☐ Other

26. How much profit do you make a year?

☐ < R500 ☐ R500- R1000 ☐ R1000- R5000 ☐R5000- R10 000 ☐R10 000- R50 000

☐ > R50 000 ☐ No response

Depredation, retaliatory practices & attitudes to wildlife

27. Which of the following animals were present at your farm/garden in the last year? Did you see the animal or only its tracks/ droppings, rough dates of sightings, and numbers seen?

Species sighted	Animal sighted	Tracks/ droppings	Date sighted	Number sighted
Baboon	☐	☐		
African wild dog	☐	☐		
Vervet monkey	☐	☐		
Leopard	☐	☐		
Honey badger	☐	☐		
Jackal	☐	☐		
Other (specify)	☐	☐		

28. Have any of your crops/livestock/game been damaged by wild animals in the last year?

☐ Yes ☐No

29. **If yes**, which animals/crops were damaged, how many/how much, estimated damage, which species you think were responsible, and what evidence made you think so:

For Crop farming

Type of crop damaged	How much damage	cost of damage	Animal responsibl	Evidence

For Livestock or Game farming

estock/ Game damage	No. of animals damage (estimate)	Animal sale price	Animal responsibl	Evidence

30. Did you ask anyone to help with the problem? ☐ Yes ☐ No. If yes, who?

_____

31. Have you killed any problem animals in the last year? ☐ Yes ☐ No ☐ No response

32. **If no,** are there any reasons why you did not kill the problem animal?

33. **If yes**, please indicate which animals were killed, how many of each species, and method(s) used:

Animal killed	Number	Method

34. Why were they killed?

_____

_____

35. How much did it cost to kill the animal (staff costs, transport, and equipment)?

_____

_____

36. Did you use any ways that were **not** harmful to animals to protect your crops/livestock/game?

☐ Yes ☐ No

If **yes**, how much did this cost? _____

37. What do you think about the following statements? *Please tick one that suites you best.*

What do you think about the following?	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
There are good things about wild animals	☐	☐	☐	☐	☐
Wild animals bring tourists and this is good for our community/ farm	☐	☐	☐	☐	☐
I want to learn more about environmental education	☐	☐	☐	☐	☐
I want to see fewer wild animals in this village	☐	☐	☐	☐	☐
Problem animals cost me money	☐	☐	☐	☐	☐
Problem animals are pests and take far more than they need	☐	☐	☐	☐	☐
Animals are God's creation and we must not harm them	☐	☐	☐	☐	☐
I want to learn more about non-harmful ways to keep wild animals away	☐	☐	☐	☐	☐
Wildlife should be kept only in fenced off areas	☐	☐	☐	☐	☐
It does not matter if wild animals kill a few of my animals/ destroy some of my crops	☐	☐	☐	☐	☐
If you remove/kill a problem animal, another one will return	☐	☐	☐	☐	☐
Killing problem animals is cheaper than protecting my crops/stock in other ways	☐	☐	☐	☐	☐

38. Are there any wild animals that you would like to see on your village or farm?

☐ Yes ☐ No ☐ No Response

39. Which wild animals would like to see on your village or farm?

_____

_____

40. Please give a reason for your answer?

_____

41. How would you like people working for Parks to help you?

_____

_____

Thank you for your time!

For official use:

Locality: _____

GPS coordinates: S_____ **E** _____

Appendix II – Conservation practitioner questionnaire

CONSENT FORM

UNIVERSITY OF WITWATERSRAND

SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCE

PhD STUDY QUESTIONNAIRE CONSENT FORM

Date : _____

Questionnaire Number: _____ **Location:** _____

Hello, my name is Nimmi Pillai and I am a PhD student at the University of the Witwatersrand in Johannesburg. I would like to invite you to participate in my research project about the interactions between people working in conservation and the communities that border protected areas.

This form is to confirm that you have understood what my study is about and that you are willing to participate in it. Either you can sign your consent yourself at the bottom of the form or I can sign that you have given me permission to proceed with the interview that will take no more than 30 minutes.

CONSENT

I hereby agree to participate in the survey study on human-animal conflict mitigation. I understand that I am participating freely and without being forced in any way to do so. I also understand that I can stop this interview at any point should I want to discontinue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me personally.

I have received the telephone number of a person to contact should I need to speak about any issues, which may arise in this interview.

I understand that my participation will remain confidential.

I understand that if possible, feedback will be given to my community on the results of the completed research.

_____ _____

Signature of participant **Date**

Signature of researcher: _____

(This document and the questionnaire will be translated into the 1st language of the participant if required)

RESPONDENT INFORMATION SHEET- CONSERVATION PRACTITIONER SURVEY

UNIVERSITY OF THE WITWATERSRAND

SCHOOL OF ANIMAL, PLANT & ENVIRONMENTAL SCIENCES

HUMAN-ANIMAL CONFLICT QUESTIONNAIRE SURVEY

Information Sheet

Hello, my name is Nimmi Pillai, a PhD student at Wits University, and I would like to invite you to participate in a questionnaire survey. In advance, thank you for agreeing to take part in this study- your time is appreciated! You have been selected as a potential respondent through a scientific liaison officer at your place of work or due to your position in the field of Wildlife Conservation derived from a Professional database. Your participation in this survey is completely voluntary and if you choose not to take part, you will not be penalised.

The survey forms part of a collaborative study between Wits University, the Endangered Wildlife Trust, the National Research Foundation and Tshwane University of Technology. This study aims to quantify conflict between co-existing subsistence farmers and animals. We are also investigating the experiences of commercial farmers with problem animals. We are interviewing individuals working for Conservation organisations or Game parks to evaluate their attitudes to and experiences with subsistence and commercial farmers. We hope that this survey will benefit rural communities, whilst protecting biodiversity.

The aim of the questionnaire is to gather information about your reserve. The information will help us find out how conservation managers feel about farmers/communities, and allow us to inspect their monitoring programmes, identify conflict hot spots and find ways for conservation managers and communities/ farmers to interact and cooperate much better. Your answers will help find out when, where and how often this conflict happens. We will also use this information to find ways to resolve the problem.

The survey will take about 30 minutes to complete. Questionnaires answered via email can be returned to seorajpillayn@tut.ac.za. Should you wish to anonymously return the questionnaire you may fax it to 086 653 1404. Great effort will be made to keep the information confidential. Contact details are only required so that the research team can give feedback on survey results. In addition, the research team may want information for further research studies to see any changes over time. Contact information will only be shared among members of the research team. If you choose to participate in this survey, you will not be prejudiced in any way. Your responses cannot be associated with your identify. If you feel uncomfortable, at any stage, you may stop and you will not be penalised in any form.

If you have any further questions about the project please feel free to contact my supervisor, Professor Neville Pillay on (011) 717 6459; Neville.Pillay@wits.ac.za or you may call me on 072 2381404. You may also report any complaints to the Human Research Ethics Committee at the University of Witwatersrand, Johannesburg.

Thank you very much for your help and time.

Nimmi Seoraj-Pillai

QUESTIONNAIRE- CONSERVATION PRACTITIONER SURVEY

SURVEY: PEOPLE WORKING IN CONSERVATION

Interviewer(s):_____ **Date:** _____

Interviewee:

1. Title _____ First name _____ Surname:_____

Participant information

2. Which conservation body do you work for?

☐ National Park ☐ Game Reserve ☐ Private Reserve ☐ Non-governmental organisation

☐ Other (please specify) _____

3. What is your occupation? _____

4. What is your first language? _____

5. Postal/Email address:_____

6. Contact number: _____

7. GPS coordinates: S_____ E _____

8. How long have you worked in conservation? _____years _____months

9. What tribal group or ethnicity do you identify with? _____ ☐ No response

10. What religion do you practice? _____ ☐ No response

11. Do you have any formal qualifications related to your position? ☐ Yes ☐ No

☐ No response

Reserve attributes

12. Total size of the site: _____ ☐ **m^2 /** ☐ **ha** 13. Elevation: _____ **m**

14. Predominant terrain: ☐ Hilly ☐ Flat ☐ Other _____

15. Does this reserve border a rural community/village/farm? ☐ Yes ☐ No

☐ 16. If yes, how often do you interact with these people?

☐ Weekly ☐ Every twee weeks ☐ Monthly ☐ Every 6 months

☐ Once a year ☐ Once every two years ☐ Other _____

17. Does the reserve have a perimeter fence? ☐ Yes ☐ No

18. Is the perimeter fence electrified? ☐ Yes ☐ No

19. What is the predominant biome of the reserve?

☐ Grassland ☐ Scrub ☐ Savannah Woodland ☐ Mixed bushveld

☐ Cultivated fields ☐ Wetland ☐ Other (specify): _____

20. Which of the following conditions/problems do you experience on your reserve?

☐ Low/high rainfall ☐ Flooding ☐ Poor veld condition

☐ Soil erosion ☐ Veld fires ☐ Disease/ parasites

☐ Poaching ☐ Tannin/alkaloid toxicity

☐ Other (specify): _____

21. Which antelope species are present on your reserve and in what numbers?

Antelope species	Numbers

22. Which of the following species on your reserve?

☐ Baboon ☐ African Wild dog ☐ Vervet monkey

☐ Leopard ☐ Honey badger ☐ Cheetah

☐ Lion ☐ Jackal ☐ Hyena

☐ Other (specify): _____

23. What is the carrying capacity of the reserve? _____

24. Is the reserve within its carrying capacity _____

25. Does the reserve have enough manpower and funds to maintain perimeter fence?

☐ Yes ☐ No

26. How often is your perimeter fences checked for wear and tear?

_____

27. How much money is spent on perimeter fence maintenance?

_____

_____

28. Do you implement trans-boundary monitoring at the reserve? ☐ Yes ☐ No

Please provide a reason for your answer.

_____

_____

Interactions with farmers and communities

29. Do you communicate with farmers bordering your reserve?

☐ Yes ☐ No

30. Do you communicate with rural communities bordering your reserve?

☐ Yes ☐ No

31. If **yes**, how often do you liaise with farmers and rural communities bordering your reserve?

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

☐ Yes ☐ No

33. If **no**, why? _____

34. If yes, please give details

_____

_____

_____

_____

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

☐ Yes ☐ No

36. If **yes**, why? _____

37. If **no**, please give details

_____

_____

_____

38. What percentage of local communities is employed at the reserve?

_____

_____

39. What do you think of community-based-natural-resource-management?

_____

_____

40. Do you have a specific animal-damage-control authority at your reserve? ☐ Yes ☐ No

41. If no, how do you deal with human-animal conflict issues?

_____

_____

_____

42. What do you think about the following statements? *(Please tick one that suites you best)*

What do you think about the following statements?	Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
Wildlife plays a very important part in our ecosystem	☐	☐	☐	☐	☐
Wildlife attracts ecotourism	☐	☐	☐	☐	☐
Agriculture wastes natural habitats	☐	☐	☐	☐	☐
Poverty is not my problem	☐	☐	☐	☐	☐
Poachers are criminals	☐	☐	☐	☐	☐
Rural communities should benefit from tourism revenue	☐	☐	☐	☐	☐
Educating communities will benefit the reserve	☐	☐	☐	☐	☐
Rural communities can make use of natural resources from/on the reserve	☐	☐	☐	☐	☐

Please return electronic responses to seorajpillayn@tut.ac.za

Thank you for your time!

Supplementary material

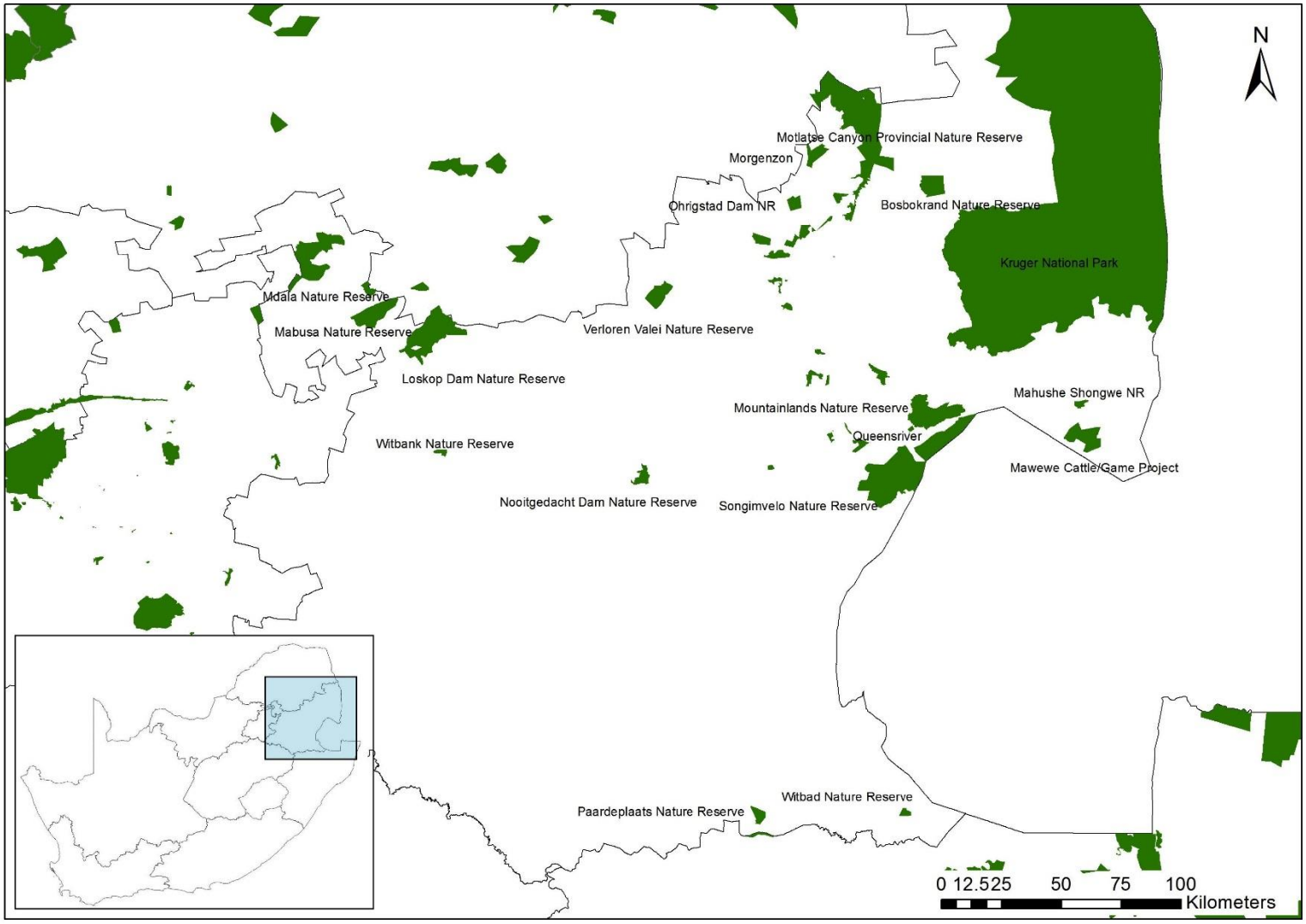


Figure S1. Formal protected areas of KwaZulu-Natal and Mpumalanga provinces, South Africa. A map of South Africa is provided in the inset.

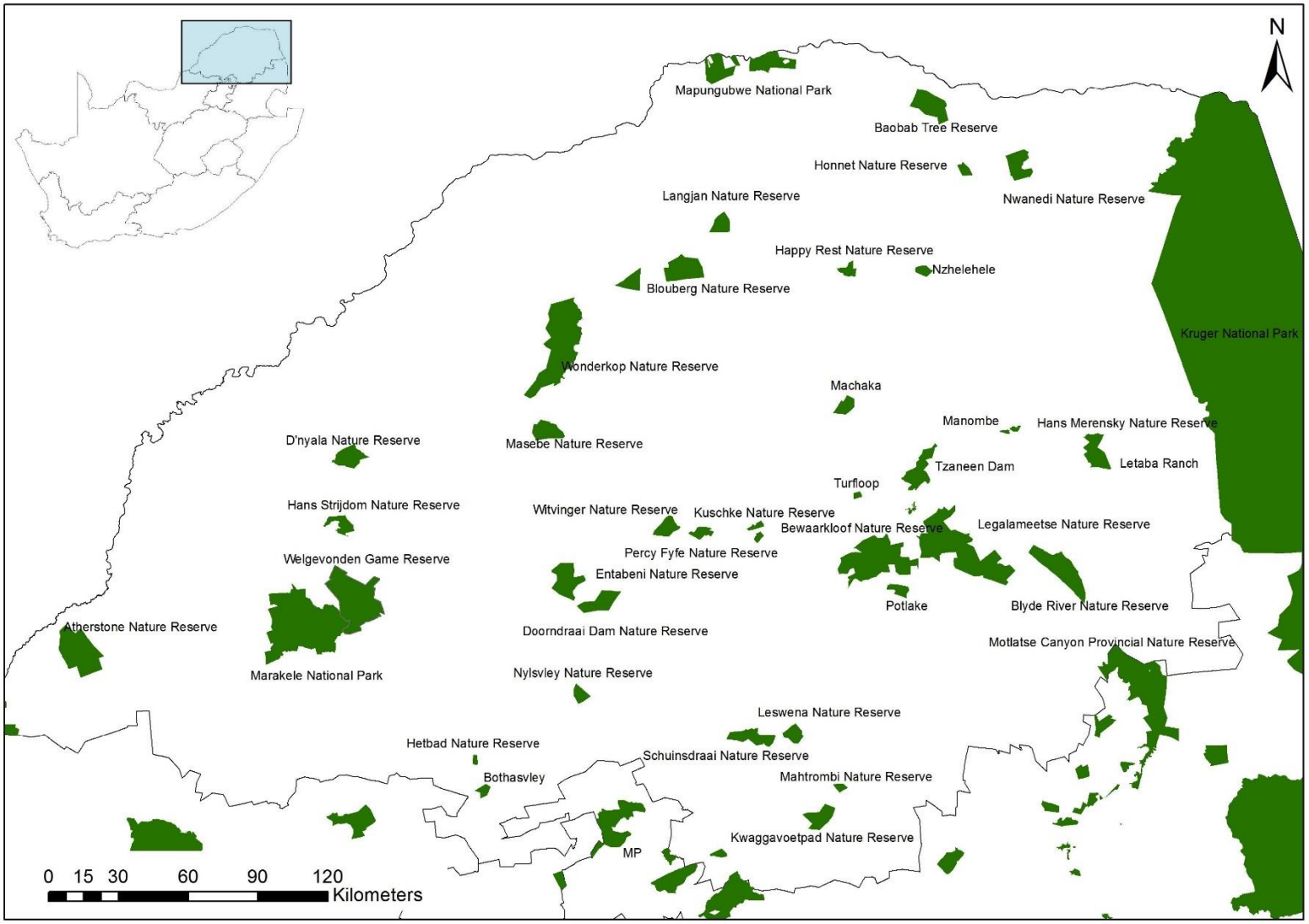


Figure S2. Formal protected areas of the Limpopo Province, South Africa. A map of South Africa is provided in the inset.















Figure S3. Photographs used to verify the identification of wild animals listed in Question 27. (photographs sourced from Google images, Digital image. n.d. In: *Google*. Retrieved from: https://www.google.co.za/images. (accessed on 09.04.2012). Species top left to bottom right: Chacma baboon *Papio ursinus*, Jaguar *Panthera onca*, Chimpanzee *Pan troglodytes*, Vervet monkey *Chlorocebus pygerythrus*, Dhole *Cuon alpinus*, Black-backed jackal *Canis mesomelas*, Leopard *Panthera pardus*, Skunk *Mephitidae* spp., Honey badger *Mellivora capensis* and African wild dog *Lycaon pictus*.

CHAPTER FOUR

Predictors of human-wildlife conflict on subsistence and commercial farming practices in north-eastern South Africa

Abstract

There is anecdotal evidence that human-wildlife conflict, combined with several environmental and socio-economic challenges, may pose a tangible threat to subsistence farmers compared with commercial farmers, but no studies have made direct comparisons between these two farming types. I investigated how subsistence and commercial farmers were affected by human-wildlife conflict in selected agri-pastoral farmland in north-eastern South Africa. I used semi-structured questionnaire interviews and inspection of premises to obtain information regarding the demographic and physical attributes of subsistence households and commercial farms that were important predictors of the occurrence and scale of human-wildlife conflict. Of the 249 farmers interviewed, 56% of commercial farmers (n = 64 of 115 interviewed) and 81% of subsistence farmers (n = 109 of 134 interviewed) reported conflict with wildlife. Subsistence farmers suffered the greatest number of crop-depredation incidences compared with commercial farmers at all study locations. There was no significant difference in the number of livestock-depredation incidences experienced by subsistence and commercial farmers. However, location differences existed, with Giyani and Komatipoort (predominantly rural areas of the Limpopo and Mpumalanga provinces respectively) reporting a significantly greater number of livestock depredation incidences than other sampled areas. Both subsistence and commercial farmers with larger households reported a significantly greater number of incidences of human-wildlife conflict than smaller households. Consistent with my prediction, subsistence farmers reported a significantly greater number of environmental-related challenges (such as insect pests, soil erosion and theft) than commercial farmers. The use of artificial irrigation was associated with significantly higher incidences of conflict for both subsistence and commercial farmers. My findings also indicated that the absence of electrified fences increased opportunities for human-wildlife conflict, especially for subsistence farmers. Human-wildlife conflict appears to affect subsistence and commercial farmers in different ways, determined by the type of farming commodity, i.e. crops, livestock or poultry, with a particular subset of predictors

exacerbating human-wildlife conflict, including crop farming, large households, environmental-related challenges and the lack of electrified fencing.

Keywords: artificial irrigation, depredators, electrified fencing, households, questionnaires

Introduction

The rapid growth of the human population has forced food production systems to transform indigenous habitats into heterogeneous agricultural farmland, primarily for livestock and crop production (Thornton et al., 2011) through commercial (Schumann et al., 2008) and subsistence (Dickman, 2010) farming. These farming practices are expected to increase in Africa to sustain an additional predicted one billion people by 2050 (Thornton et al., 2011). In a meta-analysis review of human-mammal and bird conflict (Chapter 2), I showed increased reporting of human-wildlife conflict (HWC) in developing countries. The findings of the meta-analysis showed that rural Africans and Asians were more regularly affected by encounters with damage-causing animals (DCAs) and acts of crop and livestock depredation compared with developed countries, although this could be attributed to better reporting as opposed to increased incidences of HWC.

Human-wildlife conflict occurs when the resource requirements of humans and wildlife (undomesticated terrestrial vertebrate and invertebrate animals) overlap, prompting competition for food, habitat and water and the ensuing tension between people and wildlife authorities (Woodroffe et al., 2005). Previous studies maintain that HWC may not compromise commercial agricultural production (Hill, 2000) but is a tangible threat to the marginal livelihoods of poor subsistence farmers (Hill, 2000; Sillero-Zubiri and Switzer, 2001) who additionally face several other environmental and socio-economic problems. Degradation of cropland and pasture is severe in developing countries due to heat stress, soil erosion, salinisation and erratic rainfall (Naseem and Kelly, 1999). In addition, disease and insect pests (Deng et al., 2009) together with the aforementioned abiotic factors markedly impede food production (FAO, 2015; Turpie et al., 2002), and this may cascade into food insecurity, especially for subsistence communities who have limited income to buffer the effects of adverse environmental factors (Kates and Dasgupta, 2007), thus aggravating HWC.

The natural habitats of many wild animal populations, for example large carnivores (Dickman, 2010) and primates (Hill, 2000), overlap with some of the poorest subsistence households (Dickman, 2010). In addition, the close proximity of these subsistence

communities to protected areas (PAs) elicits frequent encounters between wildlife and humans, warranting the implementation of mitigation measures such as fencing and field guards (Hemson et al., 2009) to protect crops and livestock from DCAs. However, wildlife-proof fencing, for example, is expensive and not an option for poor homesteads (Hemson et al., 2009). Electrified fencing in particular has been shown to deter DCAs and reduce HWC incidences effectively (Hayward and Kerley, 2009; Sapkota et al., 2014). Hence, the prevalence of electrified fencing could correlate negatively with HWC-related damage and thus increase the scale of HWC experienced by subsistence farmers compared with commercial farmers.

The potential consequences of HWC are exacerbated by a lack of alternate income, especially for large households of subsistence farmers (Dickman, 2010). For example, the loss of even one livestock animal through depredation can have a substantial impact upon such households (Mishra et al., 2003). Moreover, PA authorities, especially in developing countries, do not have the capacity to compensate farmers adequately for damages induced by DCAs (Naughton-Treves, 1999). Consequently, subsistence farmers who are often living in poverty find it difficult to accept biodiversity conservation of wildlife, particularly regarding DCAs (DeGeorges and Reilly, 2008), and have a low tolerance towards wildlife (Treves, 2006). Poverty, household income and household size are important socio-economic predictors of the scale of HWC (Ogra, 2008; Treves, 2006) in addition to the scarcity of critical farming resources such as fertile soil and water, all of which serve to amplify HWC (Treves, 2006).

Unique to Sub-Saharan Africa are game farms, which are defined as places where wild ungulates are raised for hunting and venison production (Cousins et al., 2008). Currently, there are approximately 9 000 game ranches and about 15 000 mixed game-livestock farms in South Africa (Cousins et al., 2008; McGranahan, 2008). Livestock losses due to human-carnivore conflict on commercial farms in Sub-Saharan Africa are estimated to be ≤5% of a cattle *Bos taurus* herd per farm per year (Butler, 2000; Thorn et al., 2012), while game farmers could potentially lose up to 50% of their wild ungulate calf population per farm per year (Cousins et al., 2008). It is assumed that commercial game farmers would have more resilience to depredation (Butler, 2000) than subsistence farmers, but if rare or expensive game and livestock species such as the roan *Hippotragus equinus* and stud cattle *Bibos* spp. are predated, the economic losses to commercial game farmers could be substantial (Van Niekerk, 2010). This may potentially affect the scale of HWC experienced by commercial game farmers compared with subsistence farmers.

South Africa comprises a dichotomy of first-world and third-world economies occurring side by side, and coupled with one of the highest levels of biodiversity in the world, South Africa affords a unique opportunity to investigate the impacts of HWC for commercial (including livestock and game farming) and subsistence farmers. In South Africa, commercial farmers own 85% of arable farmland (Armstrong et al., 2008), while subsistence farmers occupy only 15% of arable land. Most subsistence farmers are compressed into severely degraded land (Cock and Fig, 2000; Khan, 1994) and secluded from economic prospects (Armstrong et al., 2008). According to Statistics South Africa (2015), in 2014, commercial farming generated R30 billion (~US$215 million) in profits. In contrast, 58% of people living in rural areas whose dominant livelihood strategy is subsistence farming (Armstrong et al., 2008) live below the poverty line (<US$1.25 per day; Thornton et al., 2011; World Bank 2013).

Similarities and differences between subsistence and commercial farmers in South Africa are likely to occur in the impact of and resilience to HWC. Although HWC has been relatively well documented in South Africa (Thorn et al., 2012), I am not aware of any studies that compare or quantify losses due to the impact of problem animals on coexisting subsistence and commercial farmers. Commercial livestock and game farmers in South Africa have received greater scientific attention (DeGeorges and Reilly, 2008), which creates an unbalanced assessment of HWC in South Africa. For example, a questionnaire survey estimated that the annual cost accrued from depredation to the South African commercial livestock and game industry collectively, was approximately US$170 million (Van Niekerk, 2010). In addition, it appears that only commercial farmers receive compensation for livestock damages in South Africa (e.g. South African Cheetah Compensation Fund; (Cilliers, 2003). Yet, little is known about how rural South African subsistence households, the most politically disenfranchised (Cock and Fig, 2000; Khan, 1994) and economically vulnerable groups of people, are affected by HWC (DeGeorges and Reilly 2008; Mwakatobe et al., 2014).

In this study, I focus on the scale of HWC for subsistence and commercial farmers in the same geographic location to account for regional differences in exposure to HWC and DCAs and biogeographical differences in food production. This study was limited to three provinces located in north-eastern South Africa, namely Limpopo, Mpumalanga and KwaZulu-Natal, which are abundant in agricultural resources (Statistics South Africa, 2015). These provinces are also biodiverse (DeGeorges and Reilly, 2008) and are home to numerous PAs (Anthony, 2007).

Traditional definitions of HWC include retaliatory killings or deliberate persecution of wildlife (Thorn et al., 2012) by affected farmers (Hill, 2000) due to damage to property, threats to human safety, crop-raiding and livestock and/or poultry depredation by wildlife. My study specifically reports incidences of wildlife depredation of crops and livestock that may possibly lead to retaliation by people, igniting the phenomenon of HWC.

The primary aim of my study was to investigate how subsistence and commercial farmers that ranched or cultivated in the same geographic area were affected by HWC in selected localities of north-eastern South Africa. In addition, I investigated how environmental-related challenges such as irrigation, electrified fencing, soil erosion, insect pests and theft, affect crop and livestock production on subsistence and commercial farms. To achieve these aims, I used semi-structured questionnaire interviews of subsistence and commercial farmers and inspected various demographic and physical attributes of subsistence households and commercial farms that are important predictors of the scale of HWC. These included household size and income, use of artificial irrigation and type and condition of fences. I made two predictions: 1) subsistence farmers would experience a significantly higher number of incidences regarding crop and livestock depredation by problem animals than commercial farmers. This may be due to their impoverished circumstances, the close proximity of rural settlements to PAs and the lack of funds to maintain adequate livestock and crop husbandry containment such as fencing. 2) Subsistence farmers would experience a greater number of environmental-related challenges that affect crop and livestock production than commercial farmers.

Materials and methods

Data for this chapter were extracted from survey responses to the questionnaire used in Chapter 3 (Appendix I), and detailed methodology concerning data collection, sampling procedures, interview methods, general statistical analysis and geographic information system (GIS) methodology is provided in Chapter 3.

Data analysis

Detailed quantitative statistical analysis methodology is provided in Chapter 3. A Poisson error structure with a log link function was used for count data throughout the GLMM analyses, except for binary data, in which case binomial distribution was used with

the log link function, because continuous responses could be exaggerated. The Mkuze (subsistence farmer data available only) and Waterberg (commercial farmer data available only) depredation data were removed from location analyses because no comparative data was available.

Household size and household income analyses

To compare the household size or the household income of subsistence and commercial farmers, I ran a generalised linear mixed model fit by maximum likelihood test (GLMM) from the lme4 package. The model compared fixed-effect parameters (subsistence and commercial farmers) and random factors (locality: to account for unbalanced sampling of subsistence and commercial farms) and covariates (number of respondents experiencing HWC, household size and household income) in a linear predictor (a predictor that incorporates the information about the independent/fixed variables into the GLMM model) via maximum likelihood. The GLMM model can analyse count data that do not assume a normal distribution. I adapted the guidelines provided by Ogra (2008) for classification of household size, where a small household contained one to four occupants or members, a medium household contained five to six members and a large household contained seven or more occupants. Income brackets were compared to assess differences between the proportion of respondents (subsistence and commercial) who claimed to earn in the poorest income group (<R500/month) and other income ranges (R500–R10 000/ month). In addition, I also assessed which was the most common household income per month.

Examination of the number of crop and livestock depredation incidences for subsistence and commercial farmers

I analysed the type of farmer (subsistence or commercial) that experienced the greatest number of crop and livestock depredation incidences using a GLMM in which the fixed-effect parameters were subsistence and commercial farmers, and the covariates were the number of farms affected by crop raiders or livestock depredators, as well as the locality of each farmer (random factors). These factors were considered because they could account for variance in the fixed variables.

Examination of complementary and environmental factors

I examined two extrinsic factors using a GLMM model, the use of artificial irrigation and the prevalence of electrified fencing, which apply to both crop and livestock husbandry and may affect the scale of HWC. Although several environmental and ecological characteristics were considered in the questionnaire, by recording the presence or absence of artificial irrigation and electrified fencing on each farm, I considered these two physical elements important predictors of HWC. Fencing is a significant tool to deter wildlife from farms (Kesch et al., 2015). Previous studies have shown irrigation to attract wildlife onto farmland and increase opportunities for HWC (Thouless and Sakwa, 1995), especially on unfenced properties. The model compared fixed-effect parameters (subsistence and commercial farmers) and covariates that included number of respondents experiencing HWC, abiotic problems and the presence or absence of irrigation and electrified fencing, as well as location (random factor) in a linear predictor via maximum likelihood. These factors were considered because they could account for variance in the fixed variables.

Geographic information system illustrations

Details regarding GIS methodology are available in Chapter 3. The shapefiles of PAs were used as a base layer and opened first, onto which interview GPS data points from the questionnaires were overlaid to display spatially HWC in north-eastern South Africa. Separate maps were produced to display spatially: (i) the types of farmers interviewed and their proximity to PAs; (ii) their farm holdings (livestock, poultry and/or crops); and (iii) farmers that did or did not experience HWC.

Results

Composition of farm holdings

Of the 134 subsistence farmers interviewed, 71 (53%) were crop farmers, 52 (39%) were crop-livestock farmers and 10 (7.5%) were livestock farmers. One subsistence farmer did not respond to the question regarding the composition of the farm holding. In total, 115 commercial farmers were interviewed, 97 (84%) were game-livestock farmers, 11 (10%) were crop farmers, six (5%) were livestock farmers and one (1%) was a crop-livestock farmer. The geographical distribution of farm holdings of subsistence homesteads and commercial farmers surveyed during the study in north-eastern South Africa is illustrated in Fig. 1.

Characteristics of respondents

Language

All subsistence farmers from Giyani, Limpopo Province, South Africa listed Tsonga as their first language (n = 30, 100%), whereas 25% of subsistence farmers from Komatipoort, Mpumalanga Province, South Africa were Swazi speaking (n = 7) and Tsonga speaking (n = 7). A small number of subsistence farmers in Komatipoort were Zulu speaking (n = 2, 7%), while the remaining subsistence farmers from Komatipoort selected 'other' as their first language (n = 12, 43%). All KwaZulu-Natal subsistence farmers in the survey (Ndumo n = 52, 100%, Mkuze n = 24,100%) listed Zulu as their first language.

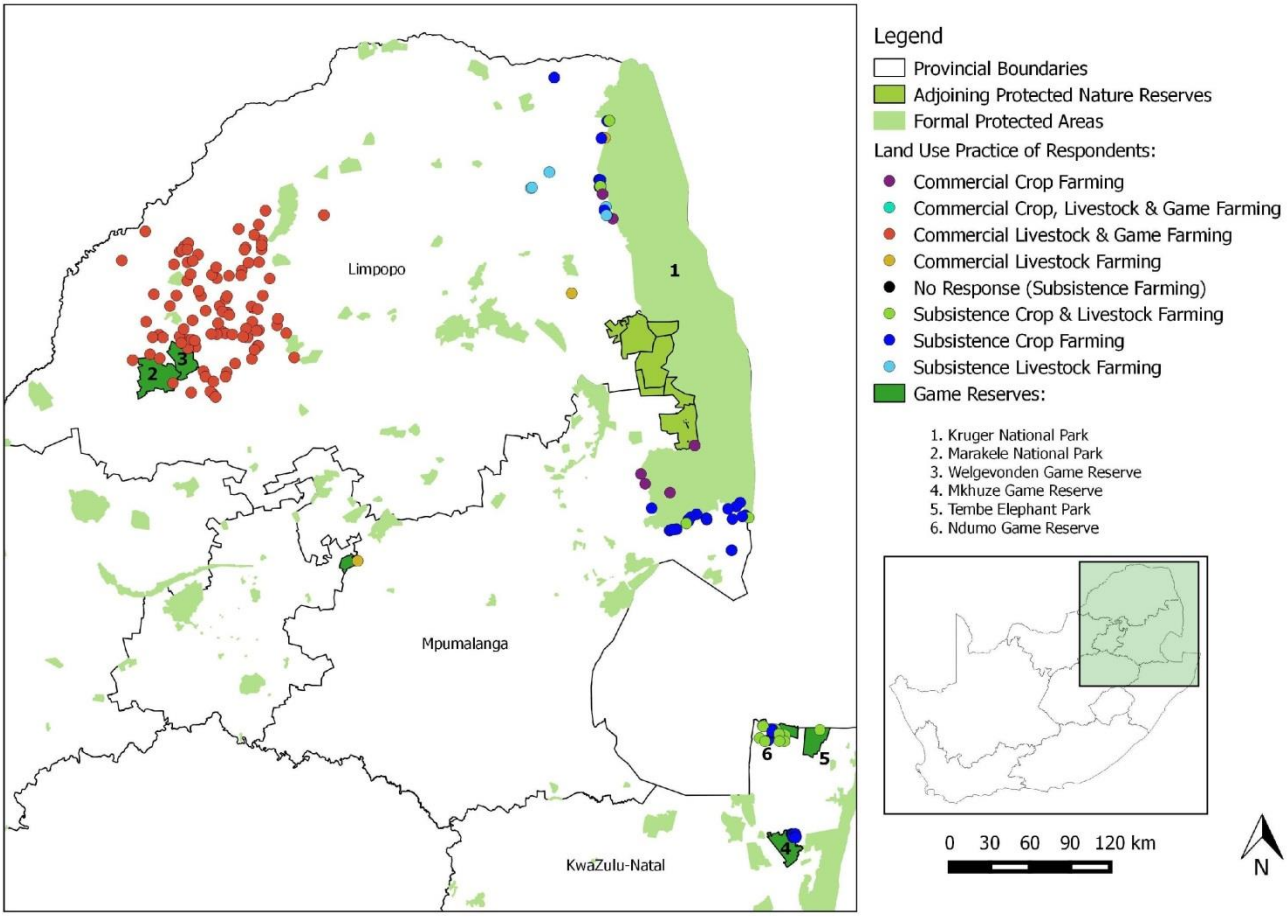


Figure 1. Location and composition of farm holdings of subsistence homesteads and commercial farmers surveyed during the study in north-eastern South Africa. A map of South Africa is provided in the inset.

The dominant first language of commercial farmers from Giyani was Tsonga (n = 8, 72%), while the other commercial farmers were Afrikaans speaking (n = 1, 9%), Zulu speaking (n = 1, 9%) or selected other languages (n = 1, 9%). The Waterberg (Limpopo

Province, South Africa) farmers did not provide their first language (n = 97). Two (40%) commercial farmers sampled in Komatipoort were Afrikaans speaking, while the remaining commercial farmers from Komatipoort selected 'other' as their first language (n = 3, 60%). The two commercial farmers from Ndumo listed Zulu as their first language (n = 2, 100%). Detailed information regarding respondent demographics is available in **Supplementary material:** S1-S3).

Ethnicity

All subsistence farmers from Giyani listed Tsonga as their ethnicity (n = 30, 100%), while the majority of subsistence farmers sampled in the Komatipoort survey did not specify their ethnicity and selected 'other' (n = 20, 71%). The remaining subsistence farmers in Komatipoort selected Swazi (n = 6, 21%), Zulu (n = 1, 4%) and no response (n = 1, 4%) for this category. All KwaZulu-Natal subsistence farmers in the survey (Ndumo n = 52, 100%, Mkuze n = 24,100%) listed Zulu as their ethnicity.

The majority of commercial farmers sampled from Giyani did not specify their ethnicity and selected 'other' (n = 10, 91%), while the one remaining commercial farmer was white (n = 1, 9%). The Waterberg farmers did not provide their ethnicity. The majority (60%) of commercial farmers sampled from Komatipoort were white (n = 3), while the remaining commercial farmers from Komatipoort selected 'other' (n = 1, 20%) or Swazi (n = 1, 20%) as their ethnicity. Commercial farmers from Ndumo listed Zulu as their ethnicity (n = 2, 100%).

Religion

The dominant religion of subsistence farmers sampled from Giyani was Christian (n = 28, 93%), and one farmer followed an African traditional religion (3%). One respondent from Giyani claimed to practise no religion (n = 1, 3%). The majority of subsistence farmers from Komatipoort reported Christianity as their religion (n = 21, 75%). The remaining subsistence farmers in Komatipoort chose 'no response' (n = 6, 21%) or 'other' (n = 1, 4%) for this category. The majority of Ndumo subsistence farmers in the survey indicated that they were Christians (n = 22, 42%), followed by 35% that were Zionists (n = 18). Smaller numbers of subsistence farmers indicated that they practised the African traditional religion (n = 3, 6%), Methodist religion (n = 2, 4%), 'other' (n = 3, 5%) or no religion (n = 2, 4%). The remaining subsistence farmers sampled from Ndumo selected 'no response' (n = 2, 4%) for this category. The Mkuze subsistence farmers did not provide their religion (n = 24).

The dominant religion of commercial farmers sampled from Giyani was Christian (n = 6, 55%), followed by African traditional religion (n = 3, 27%), then Dutch Reformed (n = 1, 9%). The remaining commercial farmer respondent from Giyani reported that he had no religion (n = 1, 9%). The Waterberg farmers (n = 97) did not provide their religion. The majority (60%) of commercial farmers from Komatipoort were Christian (n = 3), while the remaining commercial farmers from Komatipoort selected 'no response' (n = 2, 40%) for this category. Commercial farmers from Ndumo listed Christianity (n = 1, 50%) or Methodist (n = 1, 50%) as their religion.

Characteristics of reported human-wildlife conflict incidences

Farmers experiencing human-wildlife conflict

Of the 249 farmers interviewed, 173 farmers (69%) indicated that they experienced conflict with wildlife, with 64 of 115 (56%) commercial farmers having experienced encounters with DCAs and 109 of 134 (81%) interviewed subsistence homesteads having experienced HWC; the geographic distributions of these farmers are illustrated in Fig. 2a-b.

A total of 81 of 173 (47%) farmers specifically reported crop loss, of which 13 (16%) were commercial farmers and 68 (84%) were subsistence farmers. In total, 13 of 173 (8%) farmers specifically reported livestock loss, of which four (31%) were commercial farmers and nine (69%) were subsistence farmers. In total, 47 of 173 (27%) farmers specifically reported game-livestock loss. In total, 32 of 173 (18%) farmers experienced both crop and livestock depredation, all of whom were subsistence farmers.

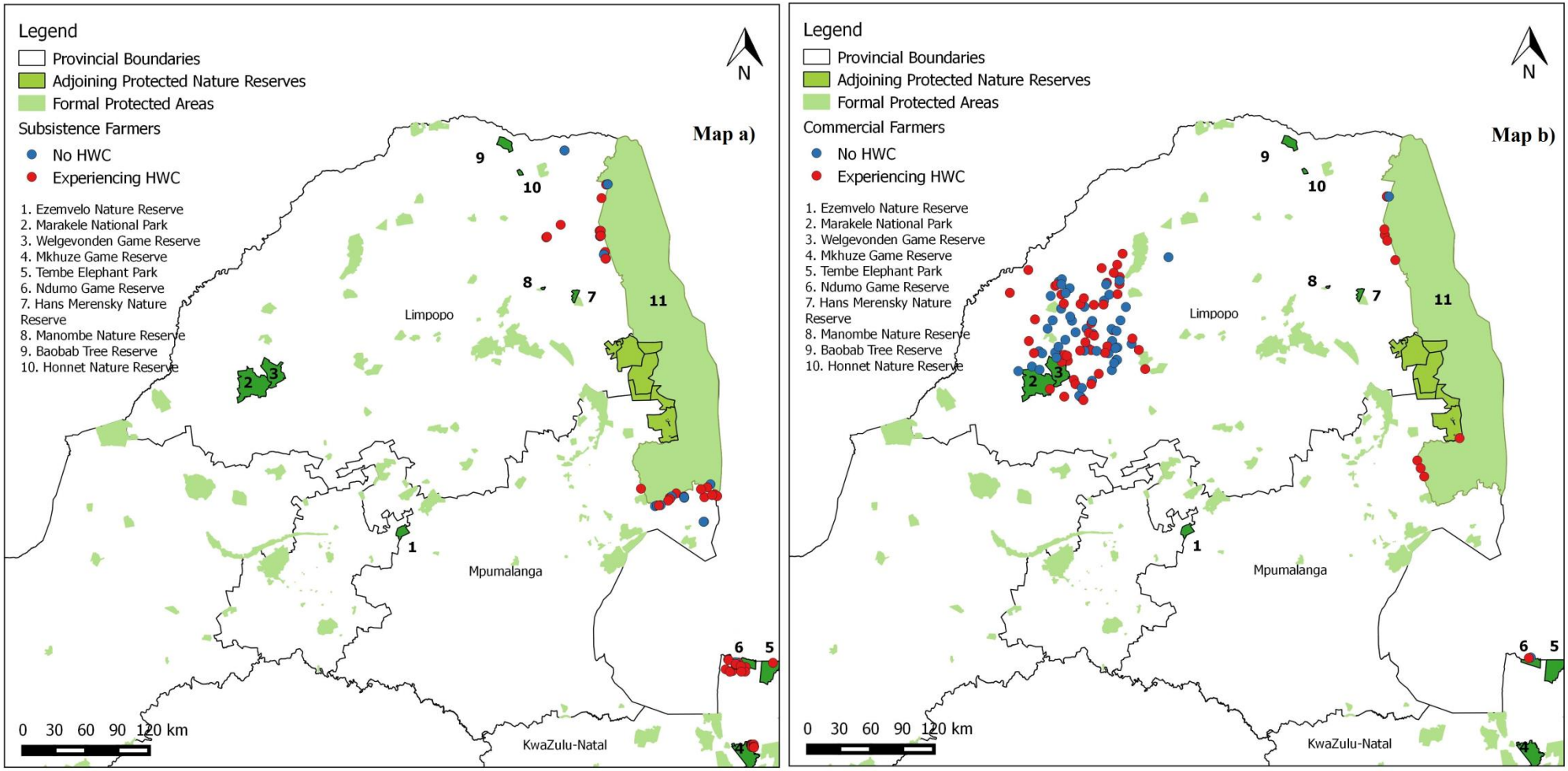


Figure 2. Comparison of the distribution of a) subsistence farmers and b) commercial farmers that did or did not experience human-wildlife conflict. Red circles are global positioning system data points that represent farms that experienced human-wildlife conflict, while blue global positioning system points are farms that did not experience human-wildlife conflict. Numbers 1−10 indicate key protected areas, while number 11 denotes the Kruger National Park.

Crop-raiding

I examined the proportion of farmers affected by crop-raiding by comparing the number of farmers affected by crop depredation against the total number of farms that grew crops (separately for subsistence and commercial farmers). Overall, subsistence farms experienced a significantly higher proportion of crop-depredation incidences than commercial farmers (Fig. 3; Table 1a). There were significant differences in the proportion of reported crop-raiding incidences between locations (random factors) with the exception of Komatipoort and Giyani that jointly experienced higher incidences of crop-depredation than other locations (Table 1b).

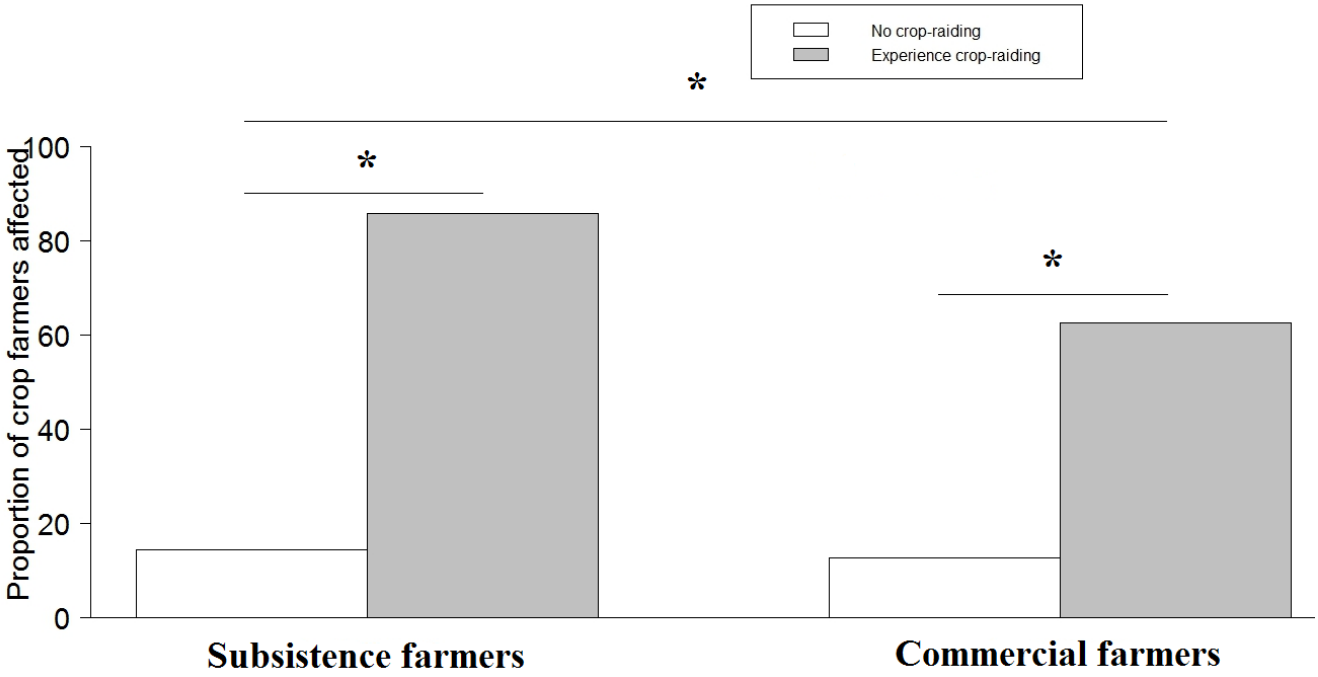


Figure 3. Proportion of subsistence and commercial crop farmers affected by crop depredation. Bars denote proportion of crop farms affected by the occurrence of crop depredation. * across or above bars represent two levels of interpretation, i.e. significant differences between farmer type and presence or absence of crop depredation. Statistics are provided in Table 1a.

Table 1. a) Output of a generalised linear mixed model by maximum likelihood comparing the proportion of subsistence and commercial farmers (fixed factors) that were affected by crop depredation, and b) Other parameters included to show statistical comparisons between locations (random factors).

Generalised linear mixed model fit by maximum likelihood			**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Higher impacted variable**	**Covariate**	**df**	**Std. Error**	**Z value**	***P***
Subsistence vs Commercial farmer	Subsistence farmer	Presence or absence of crop-raiding	5	0.08	3.77	< 0.001
Crop-raiding vs No crop-raiding	Presence of crop-raiding predominated		5	0.11	-16.31	< 0.001
b) Other parameter comparisons	**Location associated with significantly higher incidences of crop raiding**	**Random variable**	**df**	**Std. Error**	**Z value**	***P*** (for location comparisons)
Giyani vs Komatipoort	No difference	Location	52	0.10	-1.37	0.170
Giyani vs Ndumo	Giyani		52	0.11	-3.47	< 0.001
Komatipoort vs Ndumo	Komatipoort		52	0.11	-2.14	0.033

Livestock depredation

I examined the proportion of farmers affected by livestock depredation by comparing the number of farmers affected by livestock depredation with the total number of farms that farm livestock and livestock-game (separately for subsistence and commercial farmers). Farmer type did not predict the proportion of livestock farms affected (Table 2a). However, location differences existed. Giyani and Komatipoort experienced a higher proportion of livestock farms affected by depredation compared with other areas (Table 2b).

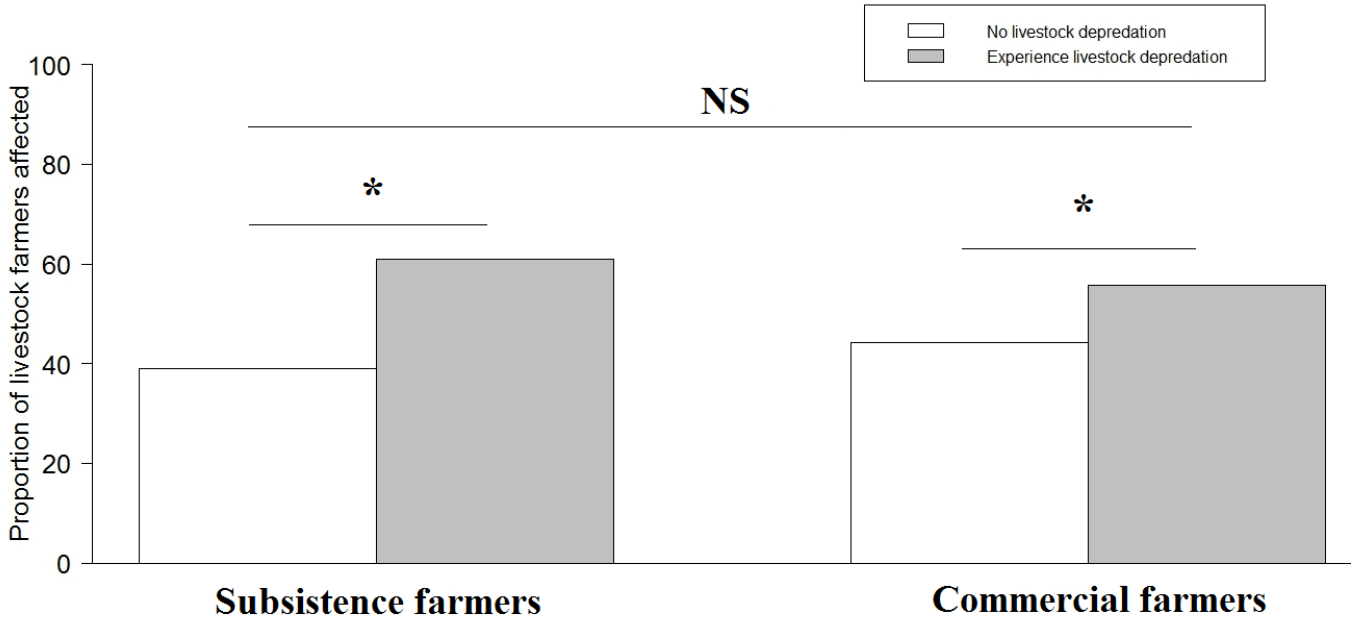


Figure 4. Proportion of subsistence and commercial livestock farmers or livestock-game farmers affected by depredation. Bars denote proportion of livestock farms affected by the occurrence of livestock depredation. * above bars represent significant differences between presence or absence of crop depredation. NS denotes no significant differences between fixed factors (farmer type). Statistics are provided in Table 2a.

Table 2. a) Comparison of subsistence and commercial farmers (fixed parameters) that experienced livestock depredation using a generalised linear mixed model by maximum likelihood, and b) Other parameters included to show statistical comparisons between locations (random factors).

Generalised linear mixed model fit by maximum likelihood			**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmers that reported significantly higher incidences**	**Covariate**	**df**	**Std. Error**	**Z value**	***P***
Subsistence vs Commercial farmer	No difference	Presence or absence of livestock depredation	13	0.07	0.00	0.990
Livestock depredation vs No livestock depredation	Presence of livestock depredation predominated		13	0.07	-4.72	< 0.001
b) Other parameter comparisons	**Location associated with significantly higher incidences of HWC**	**Covariate**	**df**	**Std. Error**	**Z value**	***P*** (for location comparisons)
Giyani vs Komatipoort	Komatipoort	Location	5	0.11	1.94	0.050
Giyani vs Ndumo	Giyani		5	0.15	-6.90	< 0.001
Komatipoort vs Ndumo	Komatipoort		5	0.15	-8.42	< 0.001

Household size of subsistence and commercial farms

Both subsistence and commercial farmer households fell into the large household category (i.e. more than seven occupants per household; Fig. 5). Commercial farmer households were significantly larger than subsistence farmer households, and both subsistence and commercial farmers with larger households reported significantly greater incidences of HWC than smaller households (Fig. 5; Table 3a). Comparison of subsistence and commercial household size per location showed that the larger commercial farm households in Komatipoort, Giyani and then Ndumo reported the presence of HWC (Table 3b).

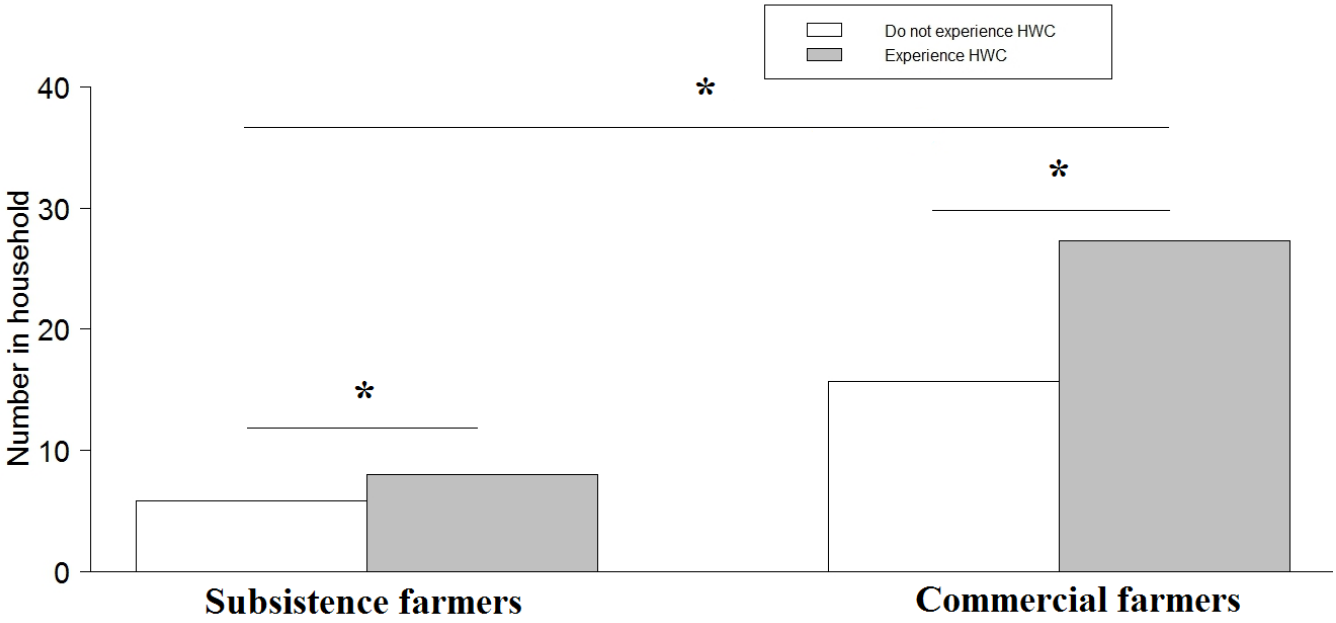


Figure 5. Household size of subsistence and commercial farmers. Bars denote number of occupants at each farm/household. * across or above bars represent two levels of interpretation, i.e. significant differences between farmer type and occurrence of human-wildlife conflict. Statistics are provided in Table 3a.

Table 3. a) Output of a generalised linear mixed model by maximum likelihood, comparing household size of subsistence and commercial farmers (fixed factors) and those who experience or do not experience conflict (covariates).

Generalised linear mixed model fit by maximum likelihood			**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Higher impacted variable**	**Covariate**	**df**	**Std. Error**	**Z value**	***P***
Subsistence vs Commercial farmer	Commercial	Presence or absence of HWC	131	0.06	-20.47	< 0.001
Farmers that experience HWC vs Farmers that do not	Farmers who experience HWC		131	0.08	-5.04	< 0.001

Table 3. b) Statistical comparisons showing the relationship between farmer type, location and the presence or absence of human-wildlife conflict.

Generalised linear mixed model fit by maximum likelihood (df=104)			Coefficient estimates for correlation of fixed effects		
b) Fixed-effect parameters: Type of farmer at each location	**Higher impacted location**	**Dominant Covariate**	**Std. Error**	**Z value**	***P*** (for location comparisons)
Giyani subsistence vs Giyani commercial	Giyani commercial	Absence of HWC	0.10	-10.77	< 0.001
Giyani commercial vs Komatipoort commercial	Komatipoort commercial	Presence of HWC	0.11	-12.8	< 0.001
Komatipoort subsistence vs Giyani commercial	Giyani commercial	Absence of HWC	0.09	6.44	< 0.001
Giyani commercial vs Ndumo commercial	Giyani commercial	Absence of HWC	0.09	-7.51	< 0.001
Ndumo subsistence vs Giyani commercial	Giyani commercial	Absence of HWC	0.23	-2.58	0.009
Giyani subsistence vs Komatipoort commercial	Komatipoort commercial	Presence of HWC	0.11	-3.12	0.002
Giyani subsistence vs Komatipoort subsistence	Giyani subsistence	Absence of HWC	0.11	16.86	< 0.001
Giyani subsistence vs Ndumo commercial	Ndumo commercial	Absence of HWC	0.09	4.78	< 0.001
Giyani subsistence vs Ndumo subsistence	Ndumo subsistence	Absence of HWC	0.23	2.077	0.039
Komatipoort subsistence vs Komatipoort commercial	Komatipoort commercial	Presence of HWC	0.11	-18.21	< 0.001
Komatipoort commercial vs Ndumo commercial	Komatipoort commercial	Presence of HWC	0.08	-14.73	< 0.001
Ndumo subsistence vs Komatipoort commercial	Komatipoort commercial	Presence of HWC	0.23	-5.21	< 0.001
Komatipoort subsistence vs Ndumo commercial	Ndumo commercial	Presence of HWC	0.11	7.62	< 0.001
Komatipoort subsistence vs Ndumo subsistence	Ndumo subsistence	Presence of HWC	0.24	3.55	< 0.001
Ndumo subsistence vs Ndumo commercial	Similar	Presence of HWC	0.23	-0.18	0.86

Household income

Interestingly, farmer type did not statistically predict household income (Tables 4–6) although significant differences between the proportion of respondents who claimed to earn in the poorest income group (<R500/month) and other income ranges (R500–R10 000/ month) occurred (Table 5). The most common household income per month reportedly fell within the R500–R5000 range (Table 4).

Table 4. Income brackets with the percentage of farmers that reportedly fell within each income bracket.

Income bracket	Percentage of farmers that reportedly fell within each range	
	Subsistence	Commercial
<R500	16	7
R500–R1 000	26	33
R1 000–R5 000	43	23
R5 000–R10 000	4	0
>R10 000	3	19
No response	8	19

Table 5. Comparison of the lowest income bracket (<R500 per month) with higher income groups.

Comparison of income brackets (df= 35)	Std. error	Z value	*P*
<R500/month vs R500–R1 000/month	0.13	7.01	< 0.001
<R500/month vs R1 001–R5 000/month	0.13	8.43	< 0.001
<R500/month vs R5 001–R10 000/month	0.29	-6.11	< 0.001
<R500/month vs >R10 000/month	0.16	-1.06	0.29

Table 6. Output of a generalised linear mixed model by maximum likelihood, comparing the percentage of farmers that reportedly fell within each income bracket.

Generalised linear mixed model fit by maximum likelihood				Coefficient estimates for correlation of fixed effects			
Fixed-effect parameters	Percentage of farmers within each income bracket	Covariate 1	Covariate 2	df	Std. Error	Z value	*P*
Subsistence vs Commercial farmer	No difference	Proportion of subsistence and commercial farmers that reportedly fell within each range	Household income	39	0.76	0.00	0.99

Complementary and environmental problems affecting subsistence and commercial farmers

Farmers reported a number of environmental-related problems. Overall, subsistence farmers reported a significantly greater number of environmental-related challenges than commercial farmers (Fig. 6; Table 7). A pair-wise comparison of environmental factors revealed that the most prominent environmental challenges experienced by subsistence farmers were insect pests, soil erosion and theft, (Fig. 6; Tables 7–8).

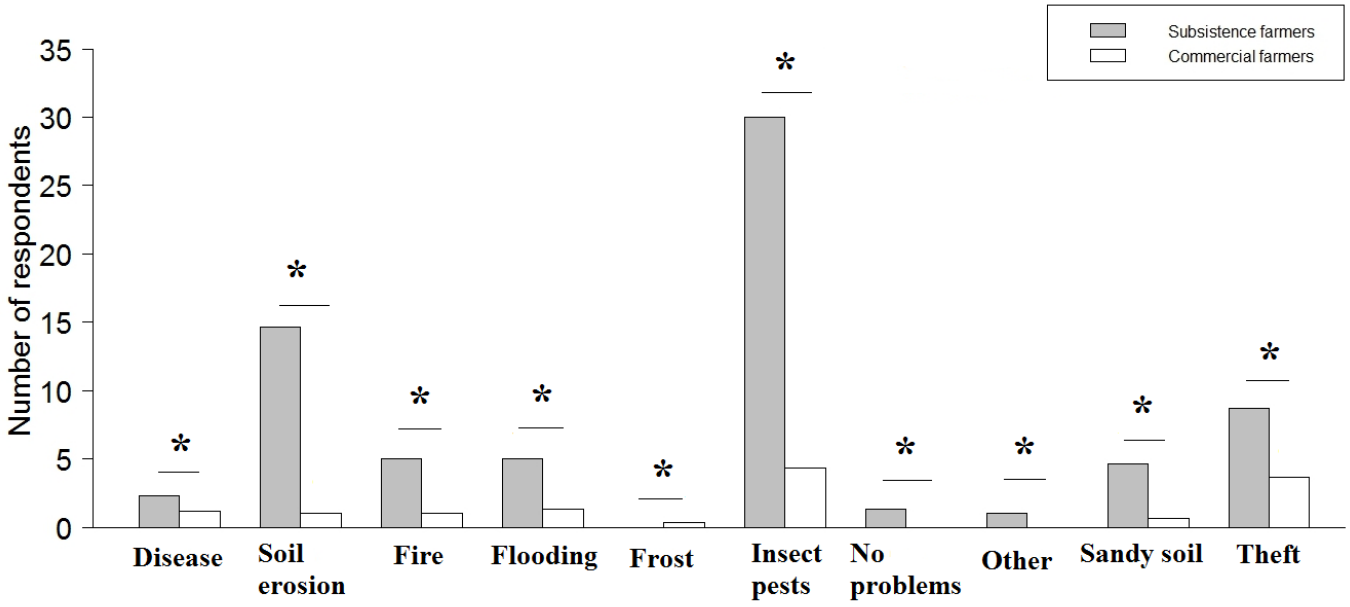


Figure 6. A comparison of environmental problems reported by subsistence and commercial farmers. Bars denote number of respondents reporting environmental challenges. * above bars represent significant differences between farmer type. Statistics are provided in Table 7.

Table 7. Output of a generalised linear mixed model by maximum likelihood, comparing environmental challenges (covariates) of subsistence and commercial farmers (fixed factors).

Generalised linear mixed model fit by maximum likelihood				**Coefficient estimates for correlation of fixed effects**			
Fixed-effect parameters	**Farmers that reported significantly higher incidences**	**Covariate 1**	**Covariate 2**	**df**	**Std. Error**	**Z value**	***P***
Subsistence vs Commercial farmer	Subsistence	Number of reports of environmental challenges	Environmental factors	63	0.16	10.00	< 0.001

Table 8. A pair-wise comparison of the leading environmental challenges reported with other factors.

Generalised linear mixed model fit by maximum likelihood		Coefficient estimates		
Comparisons	**Factor associated with significantly higher incidences of HWC**	**Std. Error**	**Z value**	***P***
Insect pest vs Disease	Insect pests	0.26	-6.92	< 0.001
Insect pest vs Soil erosion		0.18	-4.48	< 0.001
Insect pest vs Veld fire		0.25	-6.86	< 0.001
Insect pest vs Flooding		0.25	-6.80	< 0.001
Insect pest vs Frost		0.990	-4.64	< 0.001
Insect pest vs Fungus		0.51	-6.41	< 0.001
Insect pest vs No problems		0.51	-6.41	< 0.001
Insect pest vs Other		0.58	-6.07	< 0.001
Insect pest vs Bad/Sandy soil		0.27	-6.97	< 0.001
Insect pest vs Theft		0.19	-5.37	< 0.001
Soil erosion vs Disease	Soil erosion	0.28	-3.61	< 0.001
Soil erosion vs Fire		0.27	-3.48	< 0.001
Soil erosion vs Flooding		0.27	-3.35	< 0.001
Soil erosion vs Frost		0.990	-3.83	< 0.001
Soil erosion vs No problems		0.52	-4.75	< 0.001
Soil erosion vs Other		0.59	-4.64	< 0.001
Soil erosion vs Bad/Sandy soil		0.29	-3.74	< 0.001
Soil erosion vs Theft	Similar	0.22	-1.09	0.270

Irrigation

Overall, no differences were observed between farmer type and the relationship between HWC and irrigation (Fig. 7; Table 9). Both subsistence and commercial farmers who irrigated their farms reported higher incidences of HWC than the farmers who did not irrigate (Fig. 7; Table 9).

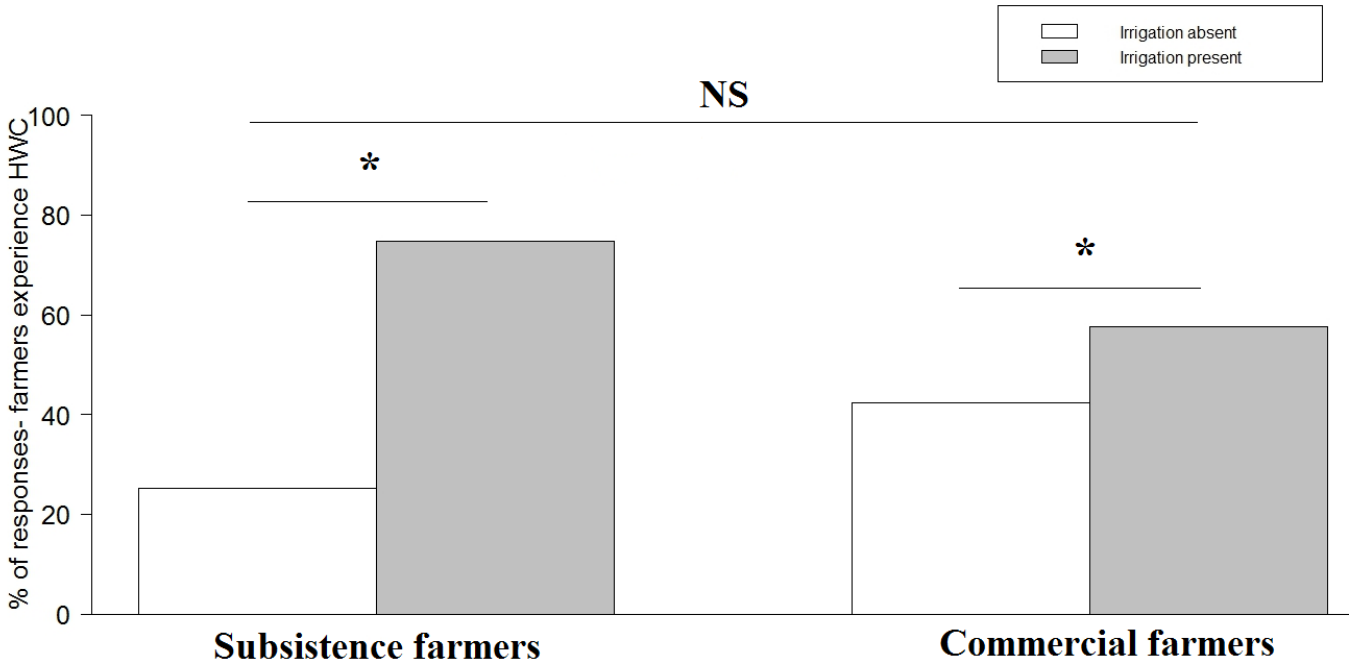


Figure 7. Comparisons showing how subsistence and commercial farmers that use and do not use irrigation were affected by incidences of human-wildlife conflict. Bars denote proportion of respondents experiencing human-wildlife conflict. * above bars represent significant differences between presence or absence of irrigation. NS denotes no significant differences between fixed factors. Statistics are provided in Table 9.

Table 9. Output of a generalised linear mixed model by maximum likelihood, comparing how the number of subsistence and commercial farmers (fixed factors) that use and do not use irrigation (covariates) were affected by incidences of human-wildlife conflict.

Generalised linear mixed model fit by maximum likelihood				**Coefficient estimates for correlation of fixed effects**			
Fixed-effect parameters	**Higher impacted variable**	**Covariate 1**	**Covariate 2**	**df**	**Std. Error**	**Z value**	***P***
Subsistence vs Commercial farmer	No difference	Percentage of responses from farmers experiencing HWC	Presence or absence of irrigation	9	0.05	0.01	0.990
Irrigation absent vs Irrigation present	Irrigation present			9	0.06	-11.05	< 0.001

There were no significant differences between farmers at each location who experienced HWC and the use of irrigation (Table 10) although, for the majority of locations, most farmers who irrigated experienced higher incidences of HWC than those who did not. However, there were two exceptions. Giyani subsistence farmers and Ndumo commercial farmers, despite not using irrigation, experienced higher incidences of HWC than the farmers who irrigated their farms in the same area (Fig. 8; Table 10).

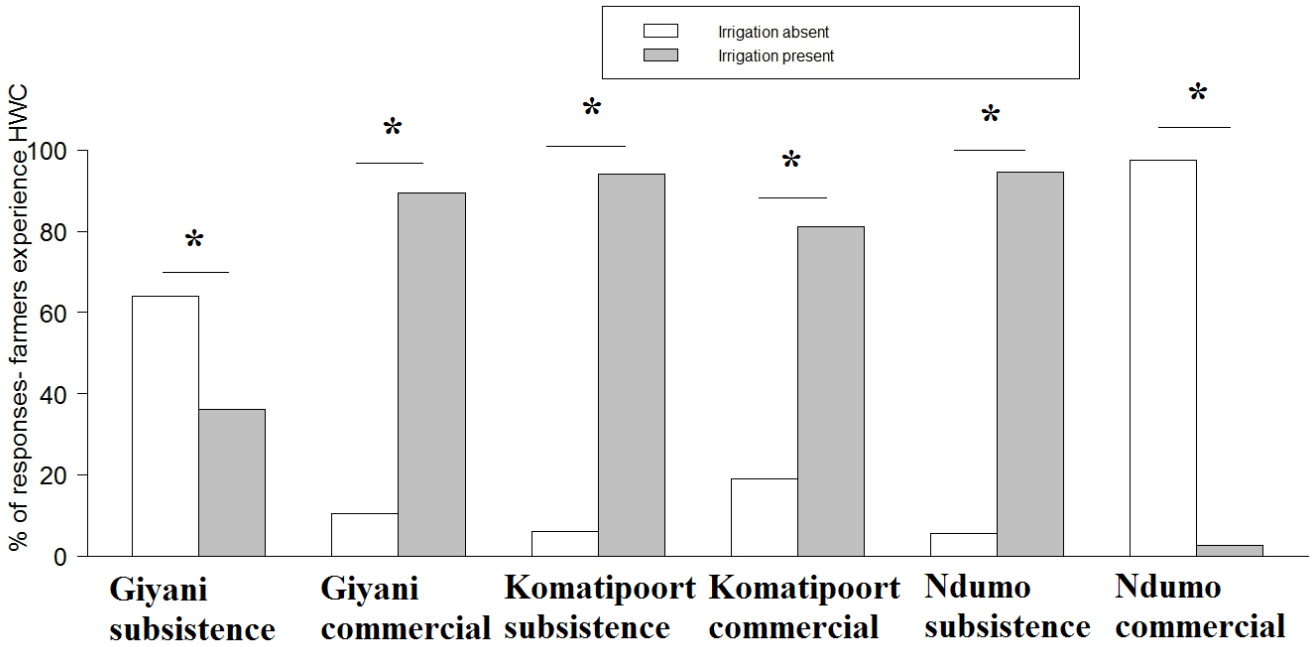


Figure 8. Comparisons showing the absence or presence of irrigation at each location that experienced human-wildlife conflict. Bars denote proportion of responses from farmers who experienced human-wildlife conflict at each location. * above bars represent significant differences between presence or absence of irrigation. Statistics are provided in Table 10.

Table 10. Output of a generalised linear mixed model by maximum likelihood that shows comparisons between subsistence and commercial farmers that experienced human-wildlife conflict (fixed factors) at each location (random factors) and which did or did not irrigate (covariates).

Generalised linear mixed model fit by maximum likelihood (df=9)			**Coefficients for location comparisons**		
Fixed-effect parameters: Type of farmer at each location	**Higher impacted variable**	**Covariate associated with significantly higher incidences of HWC**	**Std. Error**	**Z value**	***P*** (for location comparisons)
Giyani commercial vs Komatipoort commercial	No differences between locations	Presence of irrigation associated with higher incidences of HWC Significant differences between presence and absence of irrigation: SE 0.008, **Z -8.00, P <0.001**	0.14	0.00	0.990
Komatipoort subsistence vs Giyani commercial			0.14	0.00	0.990
Giyani commercial vs Ndumo commercial			0.14	0.00	0.990
Ndumo subsistence vs Giyani commercial			0.14	0.00	0.990
Giyani subsistence vs Komatipoort commercial			0.14	0.00	0.990
Giyani subsistence vs Komatipoort subsistence			0.14	0.00	0.990
Giyani subsistence vs Ndumo commercial			0.14	0.00	0.990
Giyani subsistence vs Ndumo subsistence			0.14	0.00	0.990
Komatipoort subsistence vs Komatipoort commercial			0.14	0.00	0.990
Komatipoort commercial vs Ndumo commercial			0.14	0.00	0.990
Ndumo subsistence vs Komatipoort commercial			0.14	0.00	0.990
Komatipoort subsistence vs Ndumo commercial			0.14	0.00	0.990
Komatipoort subsistence vs Ndumo subsistence			0.14	0.00	0.990
Ndumo subsistence vs Ndumo commercial	Ndumo subsistence	Absence of Irrigation	0.72	-4.54	< 0.001
Giyani subsistence vs Giyani commercial	Giyani subsistence		0.36	3.02	< 0.001

Fencing

Subsistence farmers who did not have electrified fences around their property reported higher incidences of HWC than subsistence farmers who possessed electrified fences (Fig. 9; Table 11). Commercial farmers, despite having electrified fencing around their farm perimeter, reported higher incidences of HWC than commercial farmers who did not possess electrified fencing on their property (Table 11).

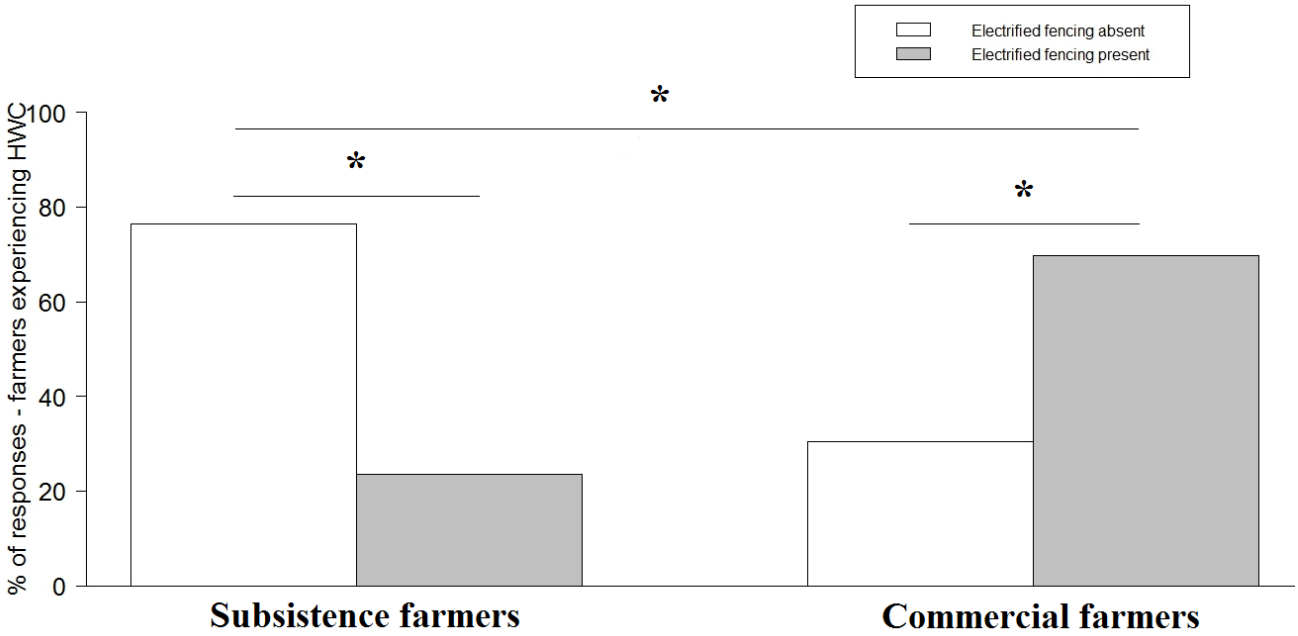


Figure 9. Comparisons showing how subsistence and commercial farmers with or without electrified fencing were affected by incidences of human-wildlife conflict. * across or above bars represent two levels of interpretation, i.e. significant differences between farmer type and prevalence of electrified fencing. Statistics are provided in Table 11.

Table 11. Output of a generalised linear mixed model by maximum likelihood, comparing how subsistence and commercial farmers (fixed factors) were affected by incidences of human-wildlife conflict in the presence or absence of wildlife-proof fencing (covariate).

Generalised linear mixed model fit by maximum likelihood				**Coefficient estimates for correlation of fixed effects**			
Fixed-effect parameters	**Farmers that reported significantly higher incidences**	**Covariate 1**	**Covariate 2**	**df**	**Std. Error**	**Z value**	***P***
Subsistence vs Commercial farmer	Subsistence	Percentage of responses from farmers experiencing HWC	Absence or presence of electrified fencing	9	0.28	6.02	0.020
Electrified fencing absent vs Electrified fencing present	Electrified fencing present			9	0.21	-2.82	0.019

The absence of electrified fences was associated with significantly greater incidences of conflict for subsistence and commercial farmers (Table 12) at all locations except for commercial farmers in Komatipoort and Ndumo who, despite the presence of electrified fencing, reported higher HWC incidences than the farmers who had no electrified fencing in the same areas (Fig. 10; Table 12).

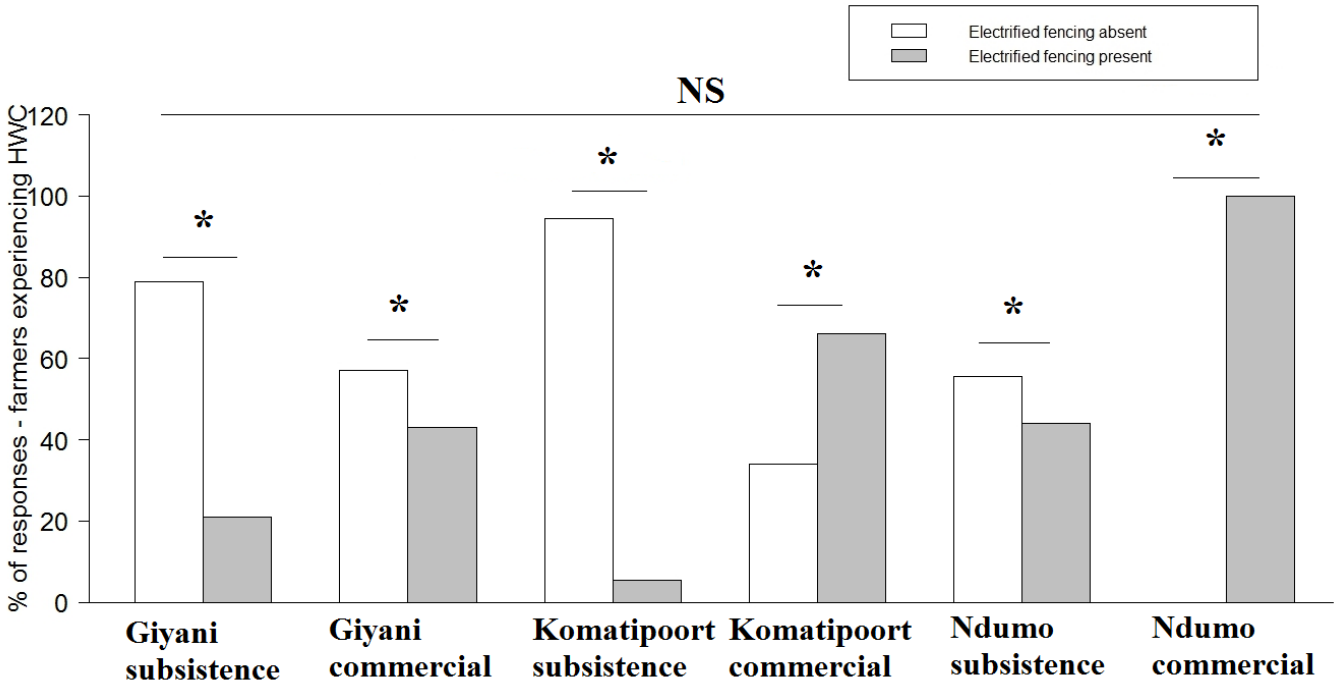


Figure 10. Comparison of how subsistence and commercial farmers at each location with or without electrified fencing were affected by human-wildlife conflict. Bars denote proportion of responses from farmers who experienced human-wildlife conflict at each location. * above bars represent significant differences between presence or absence of electrified fencing. NS denotes no significant differences between location. Statistics are provided in Table 12.

Table 12. Output of a generalised linear mixed model by maximum likelihood that shows a pairwise comparison of how subsistence and commercial farmers (fixed factors) at each location (random factors) with or without electrified fencing (covariates) were affected by human-wildlife conflict.

Generalised linear mixed model fit by maximum likelihood (df =5)			**Coefficients for location comparisons**		
Fixed-effect parameters: Type of farmer at each location	**Higher impacted variable**	**Covariate associated with significantly higher incidences of HWC**	**Std. Error**	**Z value**	***P*** (for location comparisons)
Giyani commercial vs Giyani subsistence	No difference	Absence of electrified fencing associated with higher incidences of HWC Significant differences between presence and absence of electrified fencing: **SE 0.06, Z -2.34 *P*<0.019**	0.09	0.01	0.990
Giyani commercial vs Komatipoort commercial	No difference		0.09	0.01	0.990
Giyani commercial vs Komatipoort subsistence	No difference		0.09	0.01	0.990
Giyani commercial vs Ndumo commercial	Giyani commercial		0.09	0.01	0.990
Giyani commercial vs Ndumo subsistence	Ndumo subsistence		0.10	0.05	0.960
Giyani subsistence vs Komatipoort commercial	No difference		0.09	0.01	0.990
Giyani subsistence vs Komatipoort subsistence	Komatipoort subsistence		0.09	0.01	0.990
Giyani subsistence vs Ndumo commercial	No difference		0.09	0.01	0.990
Giyani subsistence vs Ndumo subsistence	Ndumo subsistence		0.10	0.05	0.960
Komatipoort commercial vs Komatipoort subsistence	Komatipoort subsistence		0.09	0.01	0.990
Komatipoort subsistence vs Ndumo commercial	Komatipoort subsistence		0.09	0.01	0.990
Komatipoort subsistence vs Ndumo subsistence	Ndumo subsistence		0.10	0.05	0.960
Komatipoort commercial vs Ndumo subsistence	Komatipoort commercial	Presence of electrified fencing	0.20	-2.85	0.020
Ndumo commercial vs Ndumo subsistence	Ndumo commercial		0.20	-2.85	0.020

Discussion

I investigated the impact of HWC on subsistence and commercial farmers in north-eastern South Africa. My findings support the predictions that subsistence farmers would experience significantly greater incidences of crop depredation than commercial farmers, and that livestock depredators equally affected subsistence and commercial farmers. Although subsistence farmers reported a large number of environmentally-related challenges that could potentially affect crop and livestock production, this finding was driven by differing number of responses per abiotic factor which a future study with a paired sampling design of

commercial and subsistence farms can elucidate. Both subsistence and commercial farmers with larger households reported significantly greater incidences of HWC than farmers with smaller households, and the use of artificial irrigation was associated with significantly more conflict for both subsistence and commercial farmers.

Characteristics of respondents and their farm holdings

Language and ethnicities of both farmer types were typical for the indigenous South African provincial demography (Statistics South Africa, 2007). Although a large number of commercial farmers were white, Afrikaans-speaking respondents of Christian, Dutch Reformed or Methodist backgrounds, a reasonable number of commercial farmers were Tsonga from the Giyani area in Limpopo Province, South Africa. No respondents (commercial or subsistence) selected English as their first language. This could indicate a trend towards a growing number of black commercial farmers to address racially skewed land ownership (Department of Rural Development and Land Reform, 2015).

Overall, subsistence farmers experienced significantly higher incidences of crop-depredation than commercial farmers at every locality sampled. My findings were consistent with findings of studies in Uganda and Tanzania, which state that although crop-damage may not compromise commercial agricultural production, it is a tangible threat to the insecure and marginal livelihoods of poor subsistence farmers (Hill, 2000; Sillero-Zubiri and Switzer, 2001). This is of particular concern for subsistence homesteads that exist in poor areas of north-eastern South Africa, such as Giyani and Komatipoort in the provinces of Limpopo and Mpumalanga respectively, which are plagued with drought and land degradation (Statistics South Africa, 2007).

Characteristics of reported human-wildlife conflict incidences

Contrary to my predictions, no differences were detected in the proportion of livestock farmers affected by depredation, but differences between the locations occurred. The Giyani and Komatipoort farmers reported a higher proportion of livestock depredation compared with farmers in the other study locations. Giyani holds some of the lowest income earners, compressed into areas where low rainfall, low catchment of water, sedimentation of dams and degraded acid soils persist (Statistics South Africa, 2007). Hence, both subsistence and commercial livestock farmers in these areas will face environmental-related challenges and frequent incidences of livestock-depredation, all of which impede household food production. Hence, under these existing adverse conditions, it is probable that livestock

depredation will further depress the economic prospects of farmers in Limpopo and potentially compromise food security. These findings were consistent with a study in Tanzania where livestock farmers reported mean losses of about 65% of their income due to carnivore depredation (Wang and Macdonald, 2006).

Household size was an important predictor of a farmers' vulnerability or susceptibility to HWC. Both farming types with larger households reported higher incidences of HWC. It is likely that respondents from larger households were under greater pressure to provide sustenance for their families than respondents from smaller families. Hence, respondents from larger households could perceive wildlife as an increased threat to household food security and food production. My findings were consistent with a previous study in Zimbabwe that correlated larger families with negative perceptions of wildlife and conservation (Mutanga et al., 2015). Mutanga et al., (2015) postulated that larger households would require more resources and hence, develop negative perceptions towards factors that limited their livelihood (i.e. potential DCAs and the prohibition of natural resource use from PAs). A relationship between large households and farm size might be plausible, since larger farms are difficult to manage. A correlation analysis between farm size and household size separately for subsistence and commercial farms would be relevant, however not all respondents allowed their gardens to be measured. In addition, many subsistence farmers practised on communal gardens contiguous with the surrounding homes. Hence, under these conditions exact farm size could not be measured. It also plausible that no cause-and-effect relationship exists, but that a third factor, such as overall education level or cultural/religious beliefs could influence both attitudes towards wildlife and attitudes toward family planning.

Remarkably, farmer type did not predict household income. These household income results contradict government-published reports (Statistics South Africa, 2007), which state that in, South Africa, the majority of people living in rural areas live below the poverty line and rely heavily on subsistence farming to support their livelihoods. I believe that the findings regarding household income should be viewed with caution because reporting of income is a particularly sensitive issue (Ogra, 2008) and has been shown to be subject to deliberate or inadvertent exaggerations and biases by survey respondents (Rasmussen, 1999). In addition, it is possible that commercial farmers may not actually house large family groups, but the household numbers reported could include the households of resident workers.

Subsistence farmers reported a number of environmental-related issues, with soil erosion and insect pests proved to be the dominant environmental challenges. The challenges

of overcoming environmental and abiotic-related problems further intensify HWC if, for example, crops that survive heat stress, soil erosion, fungus, diseases and veld fires become vulnerable to crop-damage by DCAs at harvest time (Tweheyo et al., 2005). A study in Kenya showed that several environmental challenges (diseases, insect pests and poverty) when experienced simultaneously exacerbated crop losses for subsistence farmers (Deng et al., 2009). This study estimated that field and storage insect pests destroyed about 43% of crop yields (Deng et al., 2009).

The use of artificial irrigation was associated with significantly greater incidences of HWC for both subsistence and commercial farmers compared with farmers that did not irrigate their farms. These findings corroborated those of other studies in that the use of artificial irrigation frequently leads to HWC because water attracts wildlife either to forage on well-irrigated crops and pastures or to drink water and subsequently depredate crops (Smith and Kasiki, 2000; Thouless and Sakwa, 1995). In areas of low rainfall or during drought, artificial water points outside PAs attract wildlife into the surrounding farmland (Smith and Kasiki, 2000). Artificial irrigation is an important practice that appears to amplify opportunities for conflict and can serve to intensify the effects of HWC.

My findings indicated that the absence of electrified fences increased opportunities for HWC, especially for subsistence farmers. Subsistence households without electrified fencing experienced higher incidences of HWC, which concurs with other studies that demonstrated that electric fencing is an effective deterrent to reduce HWC incidences, disease transmission and poaching (Hayward and Kerley 2009; Sapkota et al., 2014) and decreases edge-related wildlife mortality of carnivores (Packer et al., 2013). Sapkota et al., (2014) showed that following the installation of electrical fencing, subsistence crop depredation and livestock depredation were significantly reduced by ~80% and 30–60% respectively, including reductions in human-mega-herbivore encounters. Furthermore, this study showed through a cost-benefit analysis of the installation and regular maintenance costs of electric fencing against the benefits of reducing depredations and increasing crop yields that electric fencing not only achieved monetary benefits but also significantly improved human safety and increased the quantity of crop yields (Sapkota et al., 2014). However, fencing is a contentious issue, with disadvantages such as cost of regular maintenance, ensnarement of wildlife in unkempt fencing and theft of fencing material by local communities to manufacture snares for poaching (Kesch et al., 2015).

Commercial farmers, despite having electrified fence perimeters, reported higher incidences of HWC than commercial farmers without electrified fencing (by elephant

Loxodonta africana, chacma baboon *Papio ursinus*, and leopard *Panthera pardus* according to reports in my questionnaire survey). These three species have also been described as habitual electrified fence transgressors in previous studies (Hayward *et al*., 2006; Sillero-Zubiri and Switzer, 2001; Thouless and Sakwa, 1995), and demonstrate the permeability of electrified fencing to certain species (Hayward et al., 2006; Kesch et al., 2015; Sapkota et al., 2014). The latter two species implicated in electrified fencing transgressions display substantial adjustments to anthropogenic environments like farms (Schiess-Meier et al., 2007; Sillero-Zubiri and Switzer, 2001). Sapkota et al., (2014) state in their study that although electrified fences were effective for mega-herbivore and other mammal control (the Asian elephant *Elephas maximus* and the great Indian one-horned rhinoceros *Rhinoceros unicornis*), they were less effective in deterring the porcupine *Hystrix brachyura*, the wild boar *Sus scrofa*, the tiger *Panthera tigris* and ungulates from depredation (Sapkota et al., 2014). It is also noteworthy that farmers without electrified fencing reported implementing either lethal or non-lethal control methods to deter wildlife from the farm. Moreover, previous studies have shown that the type of farming commodity and availability of water will attract wildlife irrespective of electrified fencing (Smith and Kasiki, 2000; Thouless and Sakwa, 1995).

Conclusions

My study indicated that subsistence and commercial farmers were affected by HWC in different ways, determined by the type of farming commodity present, i.e. crops, livestock or poultry, in addition to several significant predictors of incidences of wildlife conflict. These predictors included large households, use of irrigation, absence of electrified fencing and environmental-related challenges, specifically, insect pests, soil erosion and theft. Higher than average crop-raiding and livestock depredation incidences were reported for Giyani and Komatipoort in the provinces of Limpopo and Mpumalanga respectively, where farmers must overcome several environmental challenges in addition to frequent incidences of depredation, all of which impede household food production. It is possible that the combination of factors could depress economic growth of local subsistence agriculture and compromise food security. My study has provided the first comparative assessment of how subsistence and commercial farmers were affected by crop raiders in South Africa. My findings were consistent with the predicament of several other African countries, such as Uganda, Ethiopia and Tanzania, where considerable crop-raiding occurs regularly. The findings that crop-

depredation could potentially compromise household food security and nutrition were consistent with the results of the global meta-analysis of HWC (Chapter 2), concurrent with several other studies in the literature. Notably, it is also likely that the type of farmer, i.e. subsistence versus commercial, may be less important that the type of commodity farmed (i.e. monoculture and multi-crop farms or livestock small stock versus cattle farms). More focused studies can examine the type of crops/livestock types depredated in relation to the availability of crops/livestock types as well as the proximity of such farms from PA boundaries. Moreover, broad future research should identify leading crop and livestock DCAs associated with the greatest number of depredation incidences. Importantly, investigations should also consider whether or not these problem animals were common to subsistence and commercial farmers.

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Supplementary material

Table S1. Demographic data regarding first language composition (number and percentage) of subsistence and commercial farmers at each site.

Study site	Language	Number	%
Subsistence farmers			
Giyani (n = 30)	Tsonga	30	100
Komatipoort (n = 28)	Other	12	43
	Swazi	7	25
	Tsonga	7	25
	Zulu	2	7
Ndumo (n = 52)	Zulu	52	100
Mkuze (n = 24)	Zulu	24	100
Commercial farmers			
Giyani (n = 11)	Afrikaans	1	9
	Tsonga	8	72
	Zulu	1	9
	Other	1	9
Waterberg (n = 97)	No response	Did not provide information	Did not provide information
Komatipoort (n = 5)	Afrikaans	2	40
	Other	3	60
Ndumo (n = 2)	Zulu	2	100

Table S2. Demographic data regarding the ethnicity composition (number and percentage) of subsistence and commercial farmers at each site.

Study site	Ethnicity	Number	%
Subsistence farmers			
Giyani (n = 30)	Other	30	100
Komatipoort (n = 28)	Other	20	71
	Swazi	6	21
	Zulu	1	4
	No response	1	4
Ndumo (n = 52)	Zulu	52	100
Mkuze (n = 24	Zulu	24	100
Commercial farmers			
Giyani (n = 11)	Other	10	91
	White	1	9
Waterberg (n = 97)	No response	Did not provide information	Did not provide information
Komatipoort (n = 5)	Other	1	20
	Swazi	1	20
	White	3	60
Ndumo (n = 2)	Zulu	2	100

Table S3. Demographic data regarding the religion composition (number and percentage) of subsistence and commercial farmers at each site.

Study site	Religion	Number	%
Subsistence farmers			
Giyani (n = 30)	African traditional religion	1	3
	Christian	28	93
	No religion	1	3
Komatipoort (n = 28)	Christian	21	75
	No response	6	21
	Other	1	4
Ndumo (n = 52)	African traditional religion	3	6
	Christian	22	42
	Methodist	2	4
	No religion	2	4
	No response	2	4
	Other	3	5
	Zionist	18	35
Mkuze (n = 24)	No response	24	Did not provide information
Commercial farmers			
Giyani (n = 11)	African traditional religion	3	27
	Christian	6	55
	Dutch Reformed	1	9
	No religion	1	9
Waterberg (n = 97)	No response	97	Did not provide information
Komatipoort (n = 5)	Christian	3	60
	No response	2	40
Ndumo (n = 2)	Christian	1	50
	Methodist	1	50

CHAPTER FIVE

The characteristics of crop, livestock and poultry depredators in subsistence and commercial farms in north-eastern South Africa

Abstract

Retaliatory killings or deliberate persecution of wildlife by farmers due to crop, poultry and livestock depredation by damage-causing animals intensify as farming practices expand into natural habitats. My aims were to identify the most frequently depredated crops and livestock on subsistence and commercial farms as well as identify the common damage-causing animals associated with the greatest number of depredation incidences. Using semi-structured questionnaire interviews, I investigated whether or not these damage-causing animals were common to subsistence and commercial farms in selected localities of north-eastern South Africa. In addition, I investigated the lethal and non-lethal (non-harmful) control practices implemented by subsistence and commercial farmers to mitigate depredation. Subsistence farmers lost a significantly higher number of crop species to depredation than commercial farmers, with Ndumo, a subsistence community in KwaZulu-Natal Province, experiencing the greatest numbers of crop species lost. Notably, maize *Zea mays* produced by both subsistence and commercial farmers was the most frequently raided crop, and primates were reportedly responsible for the greatest number of crop-raiding incidences, particularly on subsistence farmland. Poultry and young livestock (calves/lambs/kids/foals) were most frequently depredated throughout the study locations. Joint leading depredators were caracal *Caracal caracal*, African wild dog *Lycaon pictus* and leopard *Panthera pardus*. Commercial farmers comprised a significantly greater number of respondents who practised retaliation compared with subsistence farmers, manifested as shooting and poisoning of wildlife. Commercial farmers most frequently persecuted carnivores, while subsistence farmers exclusively persecuted primates. In conclusion, wildlife depredation and persecution is the result of socioeconomic and ecological issues that are exceptionally contentious because the commodities depredated bear nutritional and financial implications for human livelihoods and the conservation of the wildlife species concerned, particularly for species that are vulnerable to extinction.

Keywords: commercial farmers, damage-causing animals, depredation, lethal control, retaliation, subsistence farmers

Introduction

The primary causes of conflict between farmers and wildlife include depredation of livestock and farmed game species, attacks on humans and crop raiding (Woodroffe et al., 2005). Depredation of farming commodities, such as crops, livestock and poultry, can occur wherever wild animals and people share the same landscapes and resources, leading to costs for both farmers and wildlife. Farmers may react with a mixture of non-lethal protective methods, such as crop and livestock guarding (Osborn and Parker, 2003), livestock and poultry enclosures (Hill, 2000; Marker et al., 2003; Treves and Karanth, 2003), or lethal control practices (Woodroffe et al., 2005), such as shooting, poisoning, trapping, gassing and electrocution (Treves and Naughton-Treves, 2005; Woodroffe et al., 2005).

Crop-raiding is a major source of human-wildlife conflict (HWC), elicited by a wide range of depredators (Saj et al., 2001) from mega-fauna (Barnes et al., 2006) such as the African elephant *Loxodonta africana* to rodents such as the rice field rat *Rattus argentiventer* (Singleton et al., 2003). In some areas, crop-raiding can become particularly intense (Mwakatobe et al., 2014). For example, in the Luangwa Valley of eastern Zambia, 11 mammalian species have been implicated in crop-raiding, while in Ruaha Tanzania, crop depredation affected about 40% of all farm crops planted (Mwakatobe et al., 2014). Depredation of crops, such as maize (Naughton-Treves, 1997) and cassava *Manihot esculenta* (Naughton-Treves, 1998), occurs frequently throughout Africa (Saj et al., 2001). The timing and frequency of crop-raids is influenced by decreased quality and nutrient content of natural forage (Fungo et al., 2013; Osborn and Parker, 2003) and the abundance of preferred crops in gardens and farms (Fungo et al., 2013).

Livestock depredation is a leading driver of HWC globally (Wang and Macdonald, 2006) and is elicited by a wide range of wildlife. In Africa, several mammalian carnivore species, such as African wild dog, African wild cat *Felis silvestris*, cheetah *Acinonyx jubatus*, civet *Civettictis civetta*, genet *Genetta genetta*, spotted hyena *Crocuta crocuta*, black-backed jackal *Canis mesomelas*, lion *Panthera leo*, leopard and the mongoose *Herpestidae illiger*, are reportedly responsible for killing livestock and game (Kissui, 2008; Schuette et al., 2013). Throughout Asia, leopard, tiger *Panthera tigris*, snow leopard *Uncia uncia*, dhole *Cuon*

alpinus and smaller cats *Felis* spp., depredate a range of livestock ranging from calves to mature bulls *Bos taurus* (Sangay and Vernes, 2008; Woodroffe and Ginsberg, 1998). Other mammals, such as baboon *Papio* spp. and honey badger *Mellivora capensis* have also contributed to livestock and poultry depredation (Davies and Du Toit, 2004; Holmern and Røskaft, 2013). According to Wang and Macdonald (2006), livestock depredation by carnivores is influenced by the type of livestock farmed, as well as the condition of livestock husbandry enclosures (security of fences and pens) and the presence/absence of deterrents (livestock guarding and shepherding) (Wang and Macdonald, 2006). Other factors that increase the frequency of depredation are predator density and natural prey availability (Holmern et al., 2007; Mishra et al., 2003; Woodroffe et al., 2005).

Costs of depredation to farmers

Crop-raiding and livestock depredation are serious sources of conflict (Hill, 2000; Siex and Struhsaker, 1999) that affect agropastoralists through the direct loss of food and income (Butler, 2000; Holmern and Røskaft, 2013; Osborn and Parker, 2003). For example, subsistence crop (potato *Solanum tuberosum* and wheat *Triticum* spp.) (Rao et al., 2002) and livestock (goat *Capra aegagrus hircus* and sheep *Ovis aries*) losses due to damage-causing animals (DCAs) in the village of Uttaranchal, India, reportedly amounted to US$15 300 and US$29 200 respectively per village in one year (Rao et al., 2002). Estimates of financial losses due to primate raiders in the village of Himachal Pradesh, India reportedly amounted to US$200 000 and US$150 000 in agriculture and horticulture respectively per village in one year (Saraswat et al., 2015). In Tanzania, livestock farmers reported losses up to 65% of their income due to carnivore depredation (Wang and Macdonald, 2006). Conner et al., (2008) estimated commercial livestock damages accruing to US$40 million annually in the United States of America (USA) alone.

Indirect costs of HWC include money to purchase and maintain deterrents such as electrified fencing and time and labour to guard or protect livestock and crops (Hill, 2004; Woodroffe et al., 2005). Hill (2004) recognised different levels of vulnerability to HWC in people based on demographic factors (age, sex, ethnicity and culture), farm location in relation to wildlife reserves, livestock, game and crop assemblages, as well as the species of problem animal concerned.

Costs of depredation to biodiversity

Human-wildlife conflict is one of the leading cause of the global decline in wildlife populations (Weber and Rabinowitz, 1996; Woodroffe et al., 2005), threatening carnivore population viability (Hemson et al., 2009) and undermining conservation initiatives (Sillero-Zubiri and Laurenson, 2001). Primates are also under threat because of retaliatory killings due to crop-raiding, including critically endangered primates such as mountain gorilla *Gorilla beringei* (Campbell-Smith et al., 2010; Hockings and Humle, 2009) and orangutan *Pongo* spp. (Campbell-Smith et al., 2010; Meijaard et al., 2011). A study of human-orangutan conflicts in Borneo revealed retaliatory killing rates of 750–1 800 individuals in one year (Meijaard et al., 2011).

Large-scale lethal extirpation of DCAs using indiscriminate methods such as poisoned bait, neck-snares, leg-hold traps, baited explosive cyanide cartridges and unselective gassing of dens (Bergstrom et al., 2014) has been shown to be ecologically damaging (Treves and Naughton-Treves, 2005) by affecting non-target species (Bergstrom et al., 2014). A striking example occurred with the kit fox *Vulpes macrotis* and swift fox *Vulpes velox* in which >95% of the total number of individuals killed since 2000 were unintentionally caught in snares set for coyote *Canis latrans* by the Wildlife Services agency, U.S. Department of Agriculture (Bergstrom et al., 2014). Additionally, the removal of conflict species, especially carnivores, that are apex predators, has had unpredictable negative ecological consequences (Treves and Naughton-Treves, 2005). Selective lethal control of targeted pest species, however, buffer or reduce depredation rates and subsequently conciliate affected farmers (Treves and Naughton-Treves, 2005).

Human-wildlife conflict involving commercial livestock farmers and carnivores in South Africa dominate the literature (Avenant and Du Plessis, 2008; Gusset et al., 2009; Swanepoel et al., 2014; Thorn et al., 2012; Thorn et al., 2015; Van Niekerk, 2010) and show that commercial ranchers perceive carnivores to be a serious economic threat to animal production (Thorn et al., 2015). Consequently, retaliatory killing and deliberate persecution of carnivores by commercial ranchers cause carnivore population declines with serious repercussions of carnivore populations (Swanepoel et al., 2014). Although crop-raiding is well researched throughout Africa, studies in South Africa are few, with the focus being on primates (Chapter 2). I am not aware of any studies in South Africa that identify and compare crop and livestock types lost to depredation on subsistence and commercial farms, or studies that identify DCAs and quantify the damages elicited by such DCAs on subsistence and

commercial farms. In this study, I consider the interactions of subsistence and commercial farmers with wildlife within the same geographic area in three provinces of South Africa, namely Limpopo, Mpumalanga and KwaZulu-Natal, which are dominated by subsistence and commercial farmlands that abut protected areas (PAs) (DeGeorges and Reilly, 2008).

The aims of this study were to: 1) identify crop species and livestock/poultry types damaged due to depredation; 2) identify the leading DCAs associated with the greatest number of crop, livestock and poultry depredation incidences; and 3) establish whether these DCAs were common to subsistence and commercial farmers in selected localities of north-eastern South Africa, using semi-structured questionnaire interviews. The specific objectives were to: 1) identify crop species and livestock/poultry types frequently depredated by DCAs; 2) identify leading DCAs associated with the greatest number of crop and livestock/poultry depredation incidences; 3) identify whether or not these DCAs were common to subsistence and commercial farmers; 4) quantify crop and livestock/poultry damages reported by subsistence and commercial farmers in monetary terms; and 5) examine the lethal and non-lethal control practices implemented by subsistence and commercial farmers to deter depredators.

I made two predictions. 1) Subsistence farmers would lose a greater diversity of crop and livestock species to DCA depredation compared with commercial farmers. In Chapter 4, I established that subsistence farmers experienced significantly more incidences of crop depredation than commercial farmers. It is probable that the type and variety of crops cultivated and livestock farmed increased opportunities for HWC. 2) Commercial farmers would implement a higher number of lethal control practices in persecution of wildlife than subsistence farmers. It is likely that commercial farmers can better afford weapons and other implements to control, kill and deter wildlife than subsistence households.

Materials and methods

Data for this chapter were extracted from survey responses to the same questionnaire as used in Chapter 3 (Appendix I), and detailed methodology concerning data collection, sampling procedures, interview methods, general statistical analysis and geographic information system (GIS) methodology is provided in Chapter 3.

Data analysis

Detailed quantitative statistical analysis methodology is provided in Chapter 3. The Mkuze (subsistence farmer data available only) and Waterberg (commercial farmer data available only) depredation data were removed from location analyses because no comparative data was available. A Poisson error structure with a log link function was used for count data throughout the generalised linear mixed model (GLMM) analyses, except for binary data, in which case binomial distribution was used with the log link function, because continuous responses could be exaggerated.

During my investigations of crop-raiding depredators, I pooled infrequently reported damage-causing mammals and non-specified damage-causing mammals into the group 'other mammals'. This included the following species: bushpig *Potamochoerus larvatus*, hippopotamus *Hippopotamus amphibius*, honey badger, mole (family *Talpidae*), mongoose *Herpestes* spp., porcupine *Hystrix* spp., rabbit (family *Leporidae*), house rat *Rattus* spp. and warthog *Phacochoerus* spp.

During my examination of livestock/poultry depredators, I pooled infrequently reported damage-causing carnivores into the group 'other carnivores'. This included the following species: bat-eared fox *Otocyon megalotis*, cheetah, spotted hyena, serval *Leptailurus serval*, striped polecat *Ictonyx striatus*, genet *Genetta genetta* and wildcat *Felis silvestris*. In addition, I pooled infrequently reported damage-causing wild animals or non-specified DCAs into the group 'other wildlife'. This included snakes (suborder *Serpentes*), eagles (genus *Aquila*) and chacma baboon *Papio ursinus*.

Identification of crop species and livestock/poultry types depredated

To analyse the damaged crop species and livestock/poultry types for subsistence and commercial farmers, I conducted a GLMM from the lme4 extension. In a linear predictor in which models were validated by maximum likelihood, the model compared fixed-effect parameters, that is, subsistence and commercial farmers and random factors, that is, locality (to account for unbalanced sampling of subsistence and commercial farms and locality-specific differences) and damaged crop species or livestock/poultry types). In addition, I analysed the number of depredation incidences per crop species or livestock/poultry type (covariates) and determined whether or not these incidences differed for subsistence and commercial farming types (fixed factors). These factors were considered because they could account for variance in the fixed variables.

Identification of damage-causing animals affecting subsistence and commercial farmers

I identified the leading DCAs for subsistence and commercial farmers by analysing the number of crop or livestock/poultry depredation incidences reported for each DCA at subsistence and commercial farms. A GLMM in a linear predictor, via maximum likelihood, was used in which the fixed-effect parameters were subsistence and commercial farmers and the covariates included number of depredation incidences per DCA.

Quantifying crop and livestock losses in monetary terms

I analysed the livestock/poultry/game damaged due to depredation from 2013–2014 in monetary terms (South African Rands) per species killed for subsistence and commercial farmers (fixed factors). I considered only the replacement value of each livestock/poultry/game individual lost, and not selling or bartering prices. I calculated, separately for subsistence and commercial livestock farmers, the unit price of each stock animal killed (**Supplementary material:** S1) multiplied by the total number of individuals reportedly depredated per species/type. I compared the financial losses incurred through each stock animal damaged (covariate) per farming type (fixed effect) using a GLMM model. Crop loss in monetary or nutritional terms could not be evaluated due to the vague or incomplete responses and non-responses regarding the quantity of crops that were damaged. Due to these omissions and inconsistencies in the survey responses, I could not quantify crop loss precisely.

Examining retaliatory methods, lethal control and non-lethal control

In my assessments of farmers who practised lethal and non-lethal control, none reported practising both lethal and non-lethal methods of control simultaneously. I identified the farmer type implementing the most retaliatory practices (covariates) by comparing the number of respondents who practised retaliation between subsistence and commercial farmers (fixed factors). I also identified the dominant retaliatory method used as a random factor in the analysis for subsistence and commercial farms, using a GLMM. I ran similar analyses to analyse lethal and non-lethal control practices by comparing the number of wild animals killed per respondent (lethal control) or the number of respondents implementing non-lethal control techniques between subsistence and commercial farmers (fixed factors).

Results

Crop-raiders

Overall, subsistence farmers lost significantly more crop species to depredation than commercial farmers (Fig. 1; Table 1a). There were significant differences in the number of damaged crop species between locations (random factors), although Giyani, Komatipoort, and Ndumo, which experienced similar numbers of crop species lost (Table 1b). Ndumo experienced the most crop species lost when compared with the other areas (Fig. 1). Although respondents from Mkuze reported a large number of crop species lost, Mkuze was removed from the analysis, since no comparative data for Mkuze was collected. Only subsistence farmers from the Mkuze area participated in the survey.

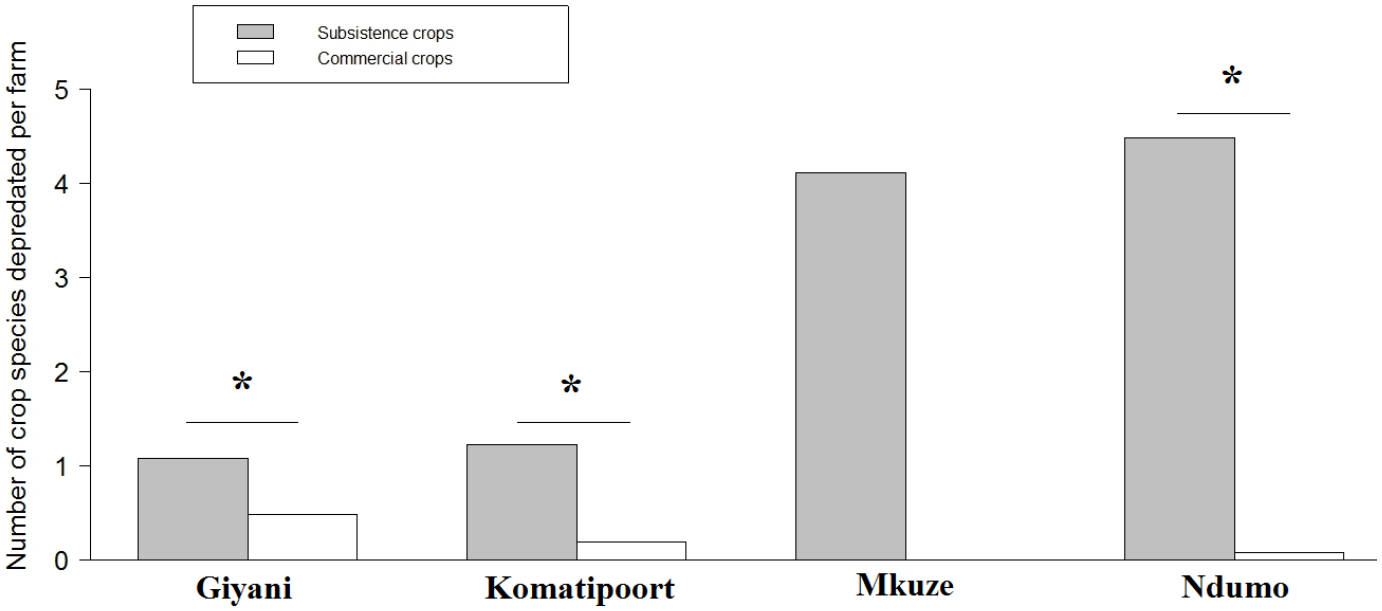


Figure 1. Comparison of the number of subsistence and commercial crop species depredated per farm at each location. Bars denote the number of crop species depredated per farm. * above bars represent significant differences between subsistence and commercial crops. Statistics are provided in Table 1a-b. No comparative data for Mkuze are provided because only subsistence farms in the Mkuze area were sampled.

Table 1. a) Output of a generalised linear mixed model by maximum likelihood, comparing the number of crop species damaged per subsistence and commercial farm (fixed factors), and b) Other parameter comparisons included to show statistical comparisons between locations (random factors).

Generalised linear mixed model fit by maximum likelihood			**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmer experiencing significantly higher number of damaged crop species**	**Random variable**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence Farmer	Subsistence	Location	187	0.23	-9.60	< 0.001
b) Other parameter comparisons	**Location associated with significantly higher incidences of crop depredation**	**Random variable**	**df**	**Std. Error**	**Z value**	***P*** (for location comparisons)
Giyani vs Komatipoort	No difference	Location	185	0.22	-0.45	0.650
Giyani vs Ndumo	Ndumo		185	0.17	6.02	< 0.001
Komatipoort vs Ndumo	Ndumo		185	0.18	6.34	< 0.001

Overall, subsistence farmers experienced a greater number of crop-raiding incidences per crop species than commercial farmers (Table 2a). Maize, produced by both subsistence and commercial farmers, was the most commonly raided crop (Table 2b).

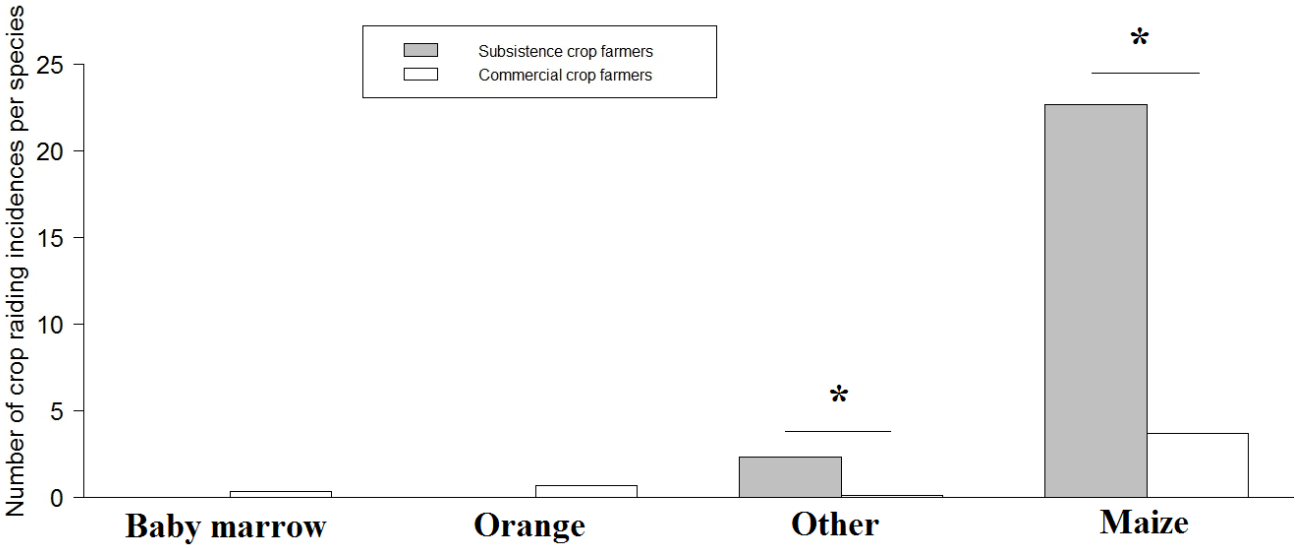


Figure 2. Comparison of the number of depredation incidences per crop species for subsistence and commercial farmers. Bars denote the number of crop-raiding incidences per crop species, including baby marrow *Cucurbita* spp., orange *Citrus* spp., maize *Zea mays* and other non-specified crops. * above bars represent significant differences between subsistence and commercial crop farmers. Statistics are provided in Table 2a-b.

Table 2. a) Output of a generalised linear mixed model by maximum likelihood, comparing number of crop-raiding incidences per crop species for subsistence and commercial farmers (fixed factors), and b) Comparisons between leading damaged crop species (maize) and other crop species.

Generalised linear mixed model fit by maximum likelihood		**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Dominant variable**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence Farmer	Subsistence	186	0.23	10.70	< 0.001
b) Comparisons between leading damaged crop species (maize) and other crop species	**Crop receiving higher number of depredation reports**	**df**	**Std. Error**	**Z value**	***P***
Maize vs Baby marrow	Maize	184	1.00	-4.6	< 0.001
Maize vs Orange		184	0.72	-5.14	< 0.001
Maize vs Other crops		184	0.13	-18.34	< 0.001

Subsistence farmers experienced a greater number of crop-raiding incidences by all DCAs reported in the survey (Fig. 3; Table 3a) than commercial farmers. Furthermore, primates were reportedly responsible for the most crop-raiding incidences on subsistence farms (Table 3b). Other crop-raiders such as mega-herbivores showed no differences in the number of crop-raids compared with antelope and birds (Fig. 3).

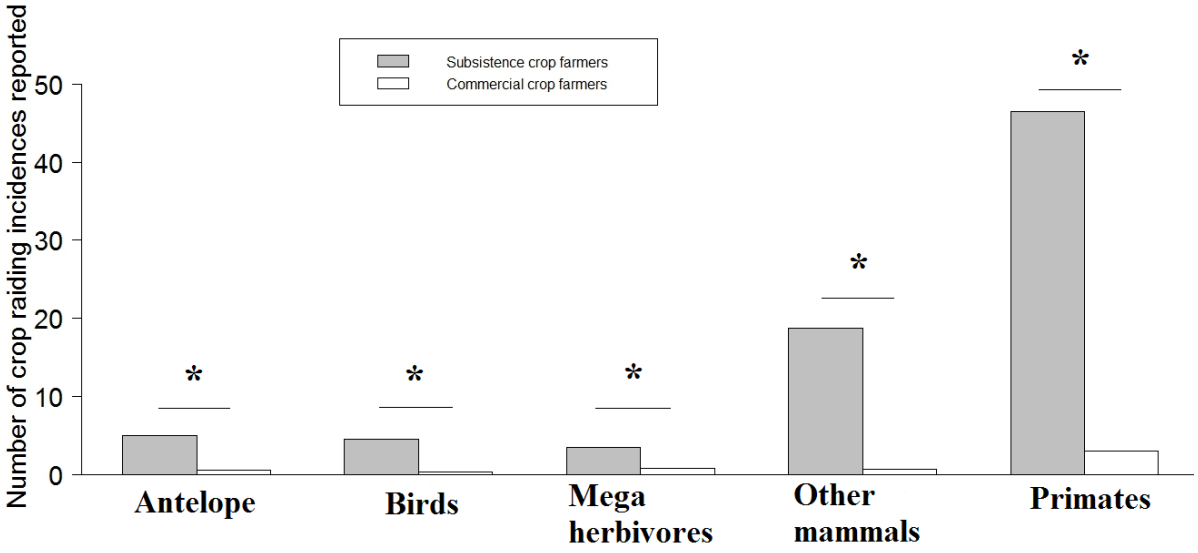


Figure 3. Comparison of the number of crop-raiding incidences by each damage-causing animal for subsistence and commercial crop farmers. Bars represent the number of crop-raiding incidences for each damage-causing animal. * above bars represent significant differences between subsistence and commercial crop farmers. Statistics are provided in Table 3a-b.

Table 3. a) Output of a generalised linear mixed model by maximum likelihood, comparing the number of crop-raiding incidences reported per damage-causing animal for subsistence and commercial crop farmers (fixed factors), and b) Comparisons between leading crop depredators (primates) and other damage-causing animals.

Generalised linear mixed model fit by maximum likelihood		**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmer experiencing higher number of raids for each DCA**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence crop farmers	Subsistence crop farmers	36	0.23	11.70	< 0.001
b) Comparisons between leading crop depredators (primates) and other DCAs	**DCAs implicated in the highest number of crop-raiding incidences**	**df**	**Std. Error**	**Z value**	***P***
Primates vs Antelope	Primates	33	0.22	-9.79	< 0.001
Primates vs Birds		33	0.24	-9.77	< 0.001
Primates vs Mega-herbivores		33	0.25	-9.73	< 0.001
Primates vs Other mammals		33	0.13	-6.91	< 0.001

Livestock, poultry and game depredators

Overall, farmer type did not influence the number of livestock/poultry species lost to depredation (Fig. 4; Table 4a). However, location differences existed (Table 4b). Giyani and Ndumo experienced the highest diversity of livestock/poultry loss to depredation (Fig. 4; Table 4b). Waterberg data was removed from the analysis because no comparative data were available for the Waterberg area. Only commercial livestock-game farms from the Waterberg participated in the survey.

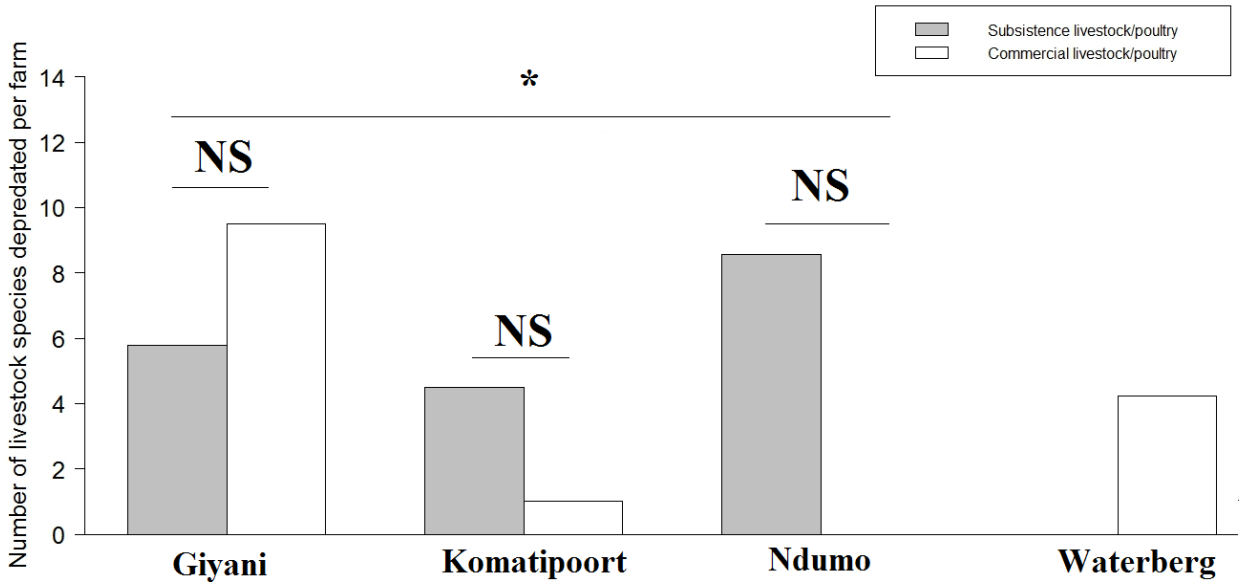


Figure 4. Comparison of the number of subsistence and commercial livestock /poultry depredated per farm at each location. Bars represent the number of livestock/poultry depredated. * across bars represent significant differences between locations. Statistics are provided in Table 4a-b. NS denotes no significant differences between farmer type. No comparative data are available for the Waterberg area because only commercial livestock-game farms participated in the survey. Commercial livestock farmers did not experience livestock depredation in the Ndumo area.

Table 4. a) Output of a generalised linear mixed model by maximum likelihood, comparing the number of livestock/poultry species damaged per subsistence and commercial farm (fixed factors), and b) Other parameters included to show statistical comparisons between locations (random factors).

Generalised linear mixed model fit by maximum likelihood			**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmer experiencing higher number of livestock/poultry sp damaged per farm**	**Covariate**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence Farmer	No difference	Number of livestock/poultry species depredated per farm	49	0.17	-0.30	0.9540
b) Other parameter comparisons	**Location associated with significantly higher incidences of depredation**		**df**	**Std. Error**	**Z value**	***P*** (for location comparisons)
Giyani vs Komatipoort	Giyani		48	0.33	-2.08	< 0.001
Giyani vs Ndumo	Ndumo		48	0.11	2.04	0.040
Komatipoort vs Ndumo	Ndumo		48	0.32	2.83	0.005

Subsistence farmers experienced a greater number of livestock/poultry-depredation incidences per species than commercial farmers (Fig. 5; Table 5a). Poultry and

calves/lambs/foals were the most frequently depredated compared with other livestock and game (Fig. 5; Table 5b).

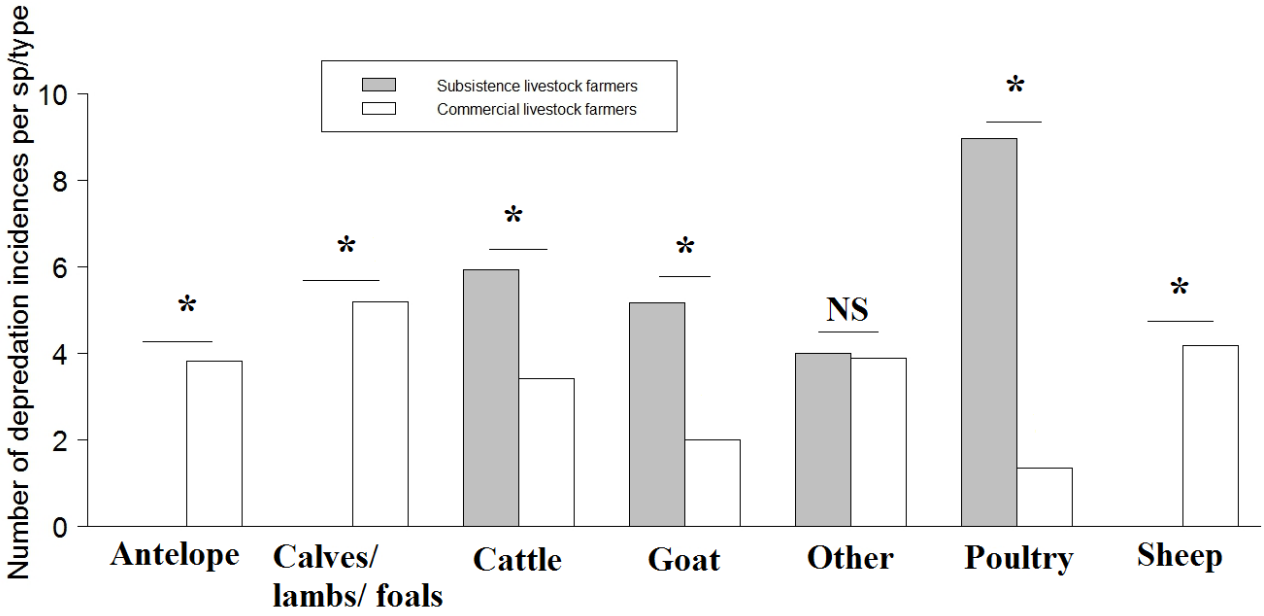


Figure 5. Comparison of the number of depredation incidences per livestock/poultry/game type for subsistence and commercial farmers. Bars represent the number of depredation incidences per livestock/poultry/game type including antelope, young stock (calves/lambs/foals), cattle, goat, other (non-specified livestock or game), poultry and sheep. * above bars represent significant differences between subsistence and commercial livestock farmers. NS denotes no significant differences between covariates. Statistics are provided in Table 5a-b. Where no data is illustrated for subsistence farmers, subsistence farmers did participate in the questionnaire and respondents reported zero incidences of depredation for that damage-causing animal.

Generally, subsistence farmers experienced a greater number of livestock-poultry depredation incidences by all DCAs featured in this study (Table 6a) compared to commercial farmers. In particular, caracal, African wild dog, leopard and 'other carnivores' (i.e. bat-eared fox, cheetah, hyena, serval, striped pole cat, genet and wild cat) were the leading depredators (Fig. 6; Table 6b). Notably, during informal discussions, respondents reported that lion in particular were a threat to the safety of orchard workers at commercial farms bordering the Kruger National Park (KNP), which was due to frequent lion boundary transgressions along the Crocodile River.

Table 5. a) Output of a generalised linear mixed model by maximum likelihood, comparing the number of reports of depredation per livestock/poultry species for subsistence and commercial farmers (fixed factors), and b) Comparisons between leading damaged species (poultry) and other species.

Generalised linear mixed model fit by maximum likelihood		**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Dominant variable**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence Farmer	Subsistence	288	0.10	4.28	< 0.001
b) Comparisons between leading species (poultry) damaged and other crop species	**Livestock/poultry receiving higher number of depredation reports**	**df**	**Std. Error**	**Z value**	***P***
Poultry vs Antelope	Poultry	283	0.14	-3.22	0.001
Poultry vs Calves	No difference	283	0.14	-1.06	0.290
Poultry vs Cattle	Poultry	283	0.12	-3.57	< 0.001
Poultry vs Goat	Poultry	283	0.17	-3.91	< 0.001
Poultry vs Other	Poultry	283	0.20	-2.28	0.023
Poultry vs Sheep	Poultry	283	0.23	-2.46	0.014

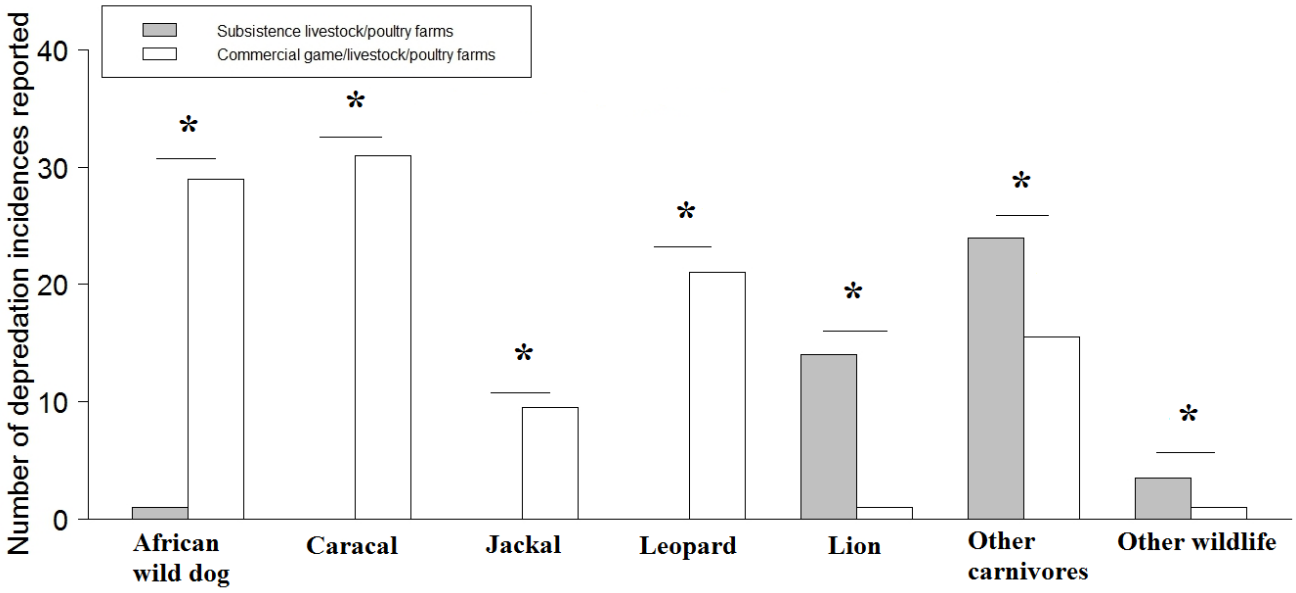


Figure 6. Comparison of the number of livestock/poultry/game depredation incidences by each damage-causing animal for subsistence and commercial farmers. Bars represent the number of depredation incidences reported per damage-causing animal. * above bars represent significant differences between subsistence and commercial livestock/poultry farmers. Statistics are provided in Table 6a-b. Where no data is illustrated for subsistence farmers, subsistence farmers did participate in the questionnaire and respondents reported zero incidences of depredation for that carnivore or other wildlife.

Table 6. a) Output of a generalised linear mixed model by maximum likelihood, comparing the number of livestock/poultry/game depredation incidences reported per damage-causing animal for subsistence and commercial livestock/poultry/game farmers (fixed factors), and b) Comparisons between leading depredator (caracal) and other damage-causing animals.

Generalised linear mixed model fit by maximum likelihood			**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmer experiencing higher number of depredation incidences for each DCA**	**Covariate**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence farmers	Subsistence	Number of depredation incidences per DCA	21	0.17	-5.97	< 0.001
b) Comparisons between leading depredators and other DCAs	**DCAs implicated in the highest number of incidences**		**df**	**Std. Error**	**Z value**	***P***
Caracal vs African wild dog	No difference on commercial farms		16	0.25	-0.98	0.330
Caracal vs Jackal	Caracal		16	0.29	-3.53	< 0.001
Caracal vs Leopard	No difference on commercial farms		16	0.21	-0.63	0.530
Caracal vs Lion	Caracal		16	0.31	-2.31	0.021
Caracal vs Other carnivores	No difference on commercial farms		16	0.21	-0.59	0.550
Caracal vs Other wildlife	Caracal		16	0.4	-4.05	< 0.001

Livestock damages for both subsistence and commercial farmers collectively amounted to R4 373 063 from 2013 to 2014 (US$275 200 at the current rand-dollar exchange rate of 1US$=R15.88) (details available in **Supplementary material:** S1). Commercial livestock farmers experienced greater financial loss due to depredation than subsistence livestock farmers (Table 7a). Overall, depredation of young livestock (calves/lambs/kids/foals) incurred the greatest financial loss compared to all other livestock/poultry/game species damaged (Table 7b).

Table 7. a) Output of a generalised linear mixed model by maximum likelihood, comparing livestock/poultry/game lost in South African Rands due to depredation for subsistence and commercial farmers (fixed factors), and b) Comparisons between leading livestock type incurring greater financial loss (calves/lambs/kids/foals) and other damaged livestock/poultry/game.

Generalised linear mixed model fit by maximum likelihood		**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmer experiencing greater financial loss due to livestock depredation**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence farmers	Commercial	38	0.01	-537.8	< 0.001
b) Comparisons between livestock types damaged	**Livestock type incurring greater financial loss**	**df**	**Std. Error**	**Z value**	***P***
Calves/lambs/kids/foals vs Antelope	Calves/lambs/kids/foals	33	0.001	-1395.2	< 0.001
Calves/lambs/kids/foals vs Cattle		33	0.001	-597.2	< 0.001
Calves/lambs/kids/foals vs Goat		33	0.004	-878.2	< 0.001
Calves/lambs/kids/foals vs Other game		33	0.003	-1058.7	< 0.001
Calves/lambs/kids/foals vs Poultry		33	0.006	-701.4	< 0.001
Calves/lambs/kids/foals vs Sheep		33	0.006	-575.4	< 0.001

Farmer retaliation and persecution of wildlife

Nine different types of retaliatory practices towards wildlife were reported, namely beating with sticks and stones, hitting with sticks, mobbing and attacking with spears, poisoning, shooting, snaring, spearing, throwing rocks and trapping (Fig. 7; Table 8a). Although subsistence farmers practised a wider range of retaliatory methods, commercial farmers comprised a significantly higher number of respondents who practised retaliation (Fig. 7; Table 8a). Shooting and poisoning were jointly the leading methods of retaliation for commercial farmers (Fig. 7; Table 8a).

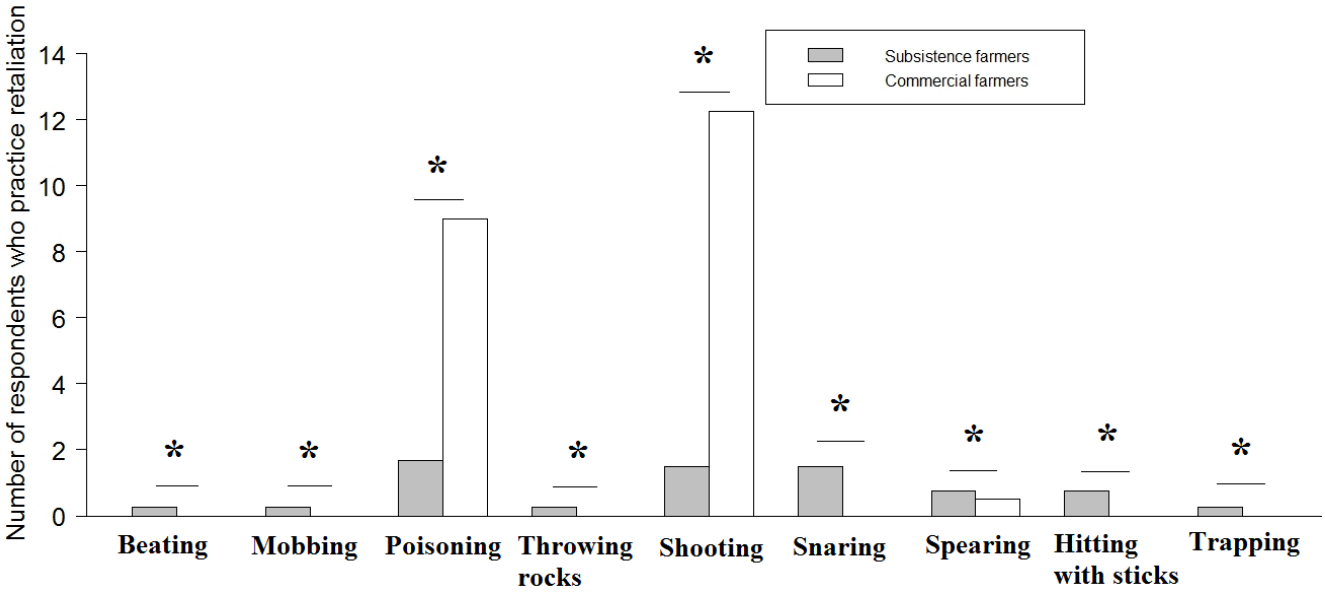


Figure 7. Comparison of the number of respondents who practise retaliation for subsistence and commercial farmers. Bars represent the number of respondents who reportedly practise retaliation for each retaliatory method. * above bars represent significant differences between subsistence and commercial farmers. Statistics are provided in Table 8a-b. Where no data is illustrated for commercial farmers, commercial farmers did participate in the questionnaire and respondents did not practise those methods of retaliation.

Table 8. a) Output of a generalised linear mixed model by maximum likelihood, comparing the number of respondents who practised retaliation for subsistence and commercial farmers (fixed factors), and b) Comparisons between leading retaliatory methods vs other retaliatory methods.

Generalised linear mixed model fit by maximum likelihood		**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmer comprising higher number of respondents who practise retaliation**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence farmers	Commercial	69	0.22	-5.02	< 0.001
b) Comparisons between leading retaliatory methods and other methods	**Dominant retaliatory method used**	**df**	**Std. Error**	**Z value**	***P***
Shooting vs Beating	Shooting	62	1.01	-3.99	< 0.001
Shooting vs Hitting with stick	Shooting	62	0.59	-4.92	< 0.001
Shooting vs Mobbing	Shooting	62	1.00	-3.99	< 0.001
Shooting vs Poisoning	No difference	62	0.20	-1.04	0.300
Shooting vs Snaring	Shooting	62	0.43	-5.17	< 0.001
Shooting vs Spearing	Shooting	62	0.47	-5.15	< 0.001
Shooting vs Throwing rocks	Shooting	62	1.00	-3.99	< 0.001
Shooting vs Trapping	Shooting	62	1.00	-3.99	< 0.001

Lethal control

Overall, 87 farmers (35% of 249) reported killing a problem animal during 2013–2014 (respondent's spatial distribution available in **Supplementary material:** Fig. S1). These comprised 60% commercial farmers (n = 52 of 87) and 40% subsistence farmers (n = 35 of 87). Commercial farmers reportedly implemented more lethal control practices than subsistence farmers (Fig. 8; Table 9a). Carnivores (excluding leopard) were the most frequently persecuted conflict species by commercial farmers (Figs. 8-9; Table 9b). Leopard and 'other mammals' displayed similar trends due to lethal control (Fig. 8; Table 9b). In addition, 'other mammals' (e.g. bushpig, hippopotamus, honey badger, mole, mongoose, porcupine, rabbit, rat and warthog) were reportedly killed on sampled subsistence and commercial farms. Primates such as chacma baboon and vervet monkey *Chlorocebus pygerythrus*, were reportedly killed on sampled subsistence farms only. Subsistence farmers (and not commercial farmers) persecuted primates (Figs. 8-9).

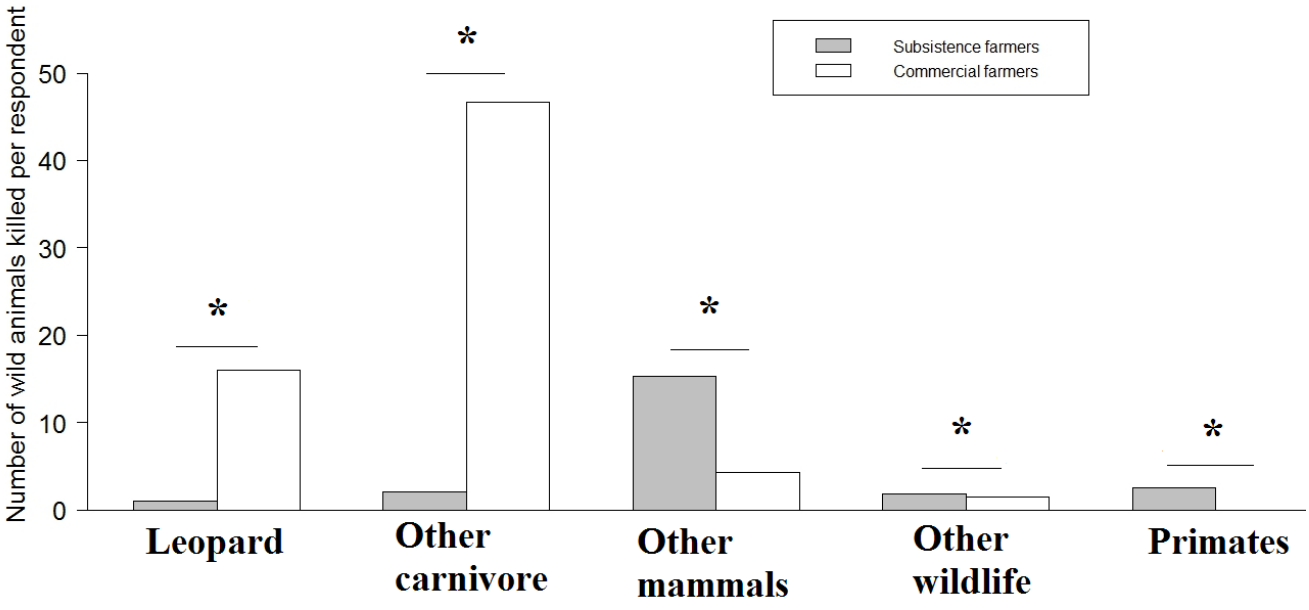


Figure 8. Comparison of the number of wild animals killed per respondent for subsistence and commercial farmers Bars represent the number and type of wildlife killed per respondent. * above bars represent significant differences between subsistence and commercial farmers. Statistics are provided in Table 9a-b.

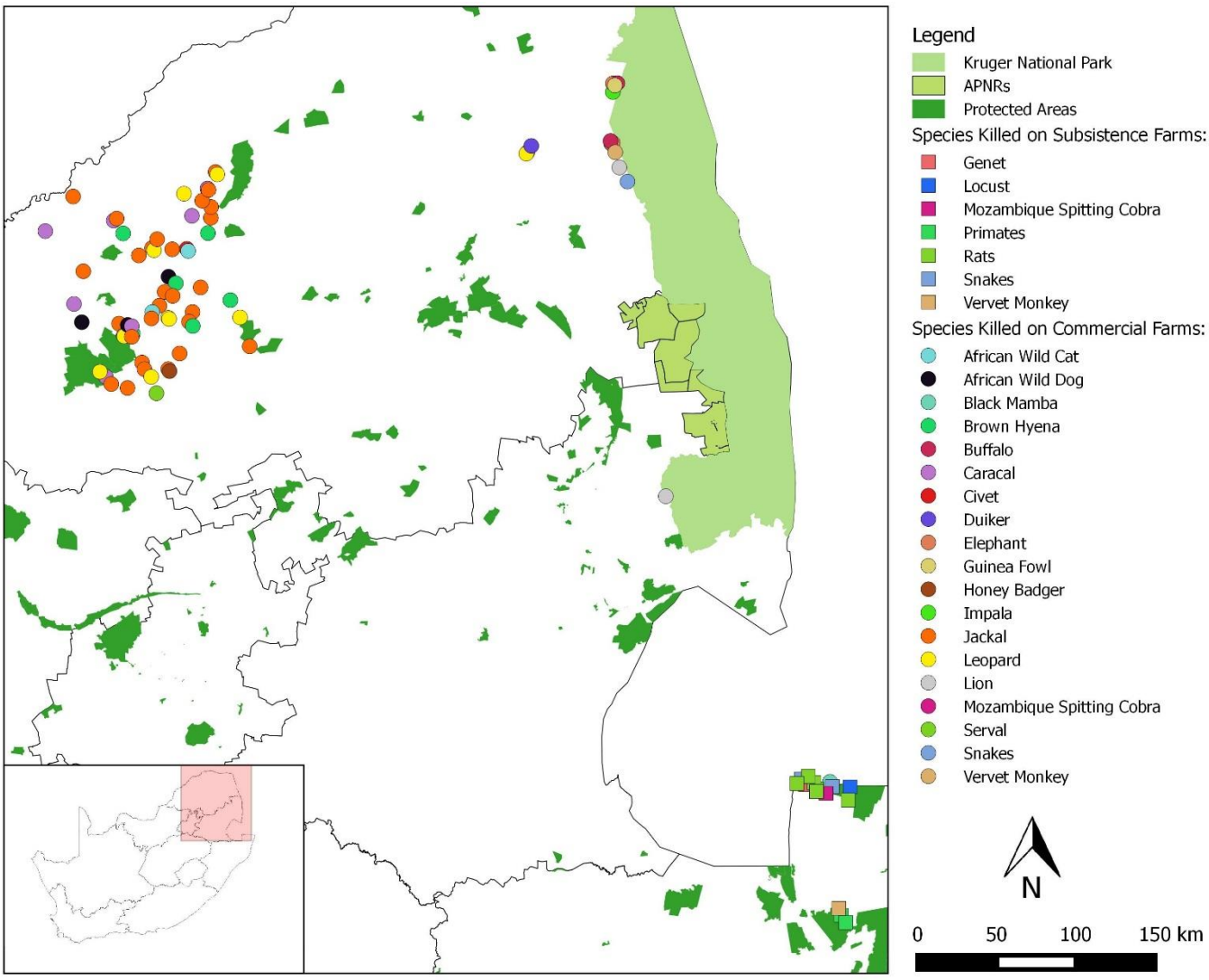


Figure 9. Distribution of animals reportedly killed by farmers during this study in north-eastern South Africa. Coloured squares indicate species killed on subsistence farms, while coloured circles represent species killed on commercial farms. A map of South Africa is provided in the inset.

According to the map illustrating the distribution of animals reportedly killed by respondents, carnivores were mainly killed in the Waterberg area, Limpopo Province, while a wide range of wildlife, such as primates, rodents and reptiles were persecuted in KwaZulu-Natal Province (Fig. 9).

Table 9. a) Output of a generalised linear mixed model by maximum likelihood, comparing the type and number of animals killed per respondent for subsistence and commercial farmers (fixed factors), and b) Comparisons between leading persecuted species (carnivores other than leopards) and other problem animals.

Generalised linear mixed model fit by maximum likelihood		**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Farmer practising highest levels of lethal control**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence farmers	Commercial	25	0.13	-5.62	< 0.001
b) Comparisons between leading persecuted species and other problem animals	**Most persecuted conflict species**	**df**	**Std. Error**	**Z value**	***P***
Other carnivores vs Leopards	Other carnivores	22	0.25	-5.11	< 0.001
Other carnivores vs Other mammals		22	0.13	-8.78	< 0.001
Other carnivores vs Other wildlife		22	0.30	-9.13	< 0.001
Other carnivores vs Primates		22	0.45	-6.17	< 0.001

Non-lethal control

No farmers reported practising both lethal and non-lethal methods of control simultaneously. In total, 137 farmers (55% of 249) claimed to implement non-harmful techniques to protect their livestock, poultry and crops from DCAs, citing kraaling (or penning) of livestock, fencing, livestock guarding, use of scarecrows and insect repellents as wildlife deterrents. Some respondents reported using a combination of wildlife deterrents to control depredation. These comprised 55% commercial farmers (n = 75 of 137) and 45% subsistence farmers (n = 62 of 137) (respondent's spatial distribution available in **Supplementary material:** Fig. S2). Farmer type did not predict non-lethal control use (Table 10). However, the use of non-lethal control dominated over the absence of non-lethal control.

Table 10. Output of a generalised linear mixed model by maximum likelihood, comparing the number of subsistence and commercial farmers (fixed factors) that use and do not use non-lethal, non-harmful control methods (covariates) to control problem animals.

Generalised linear mixed model fit by maximum likelihood				Coefficient estimates for correlation of fixed effects			
Fixed-effect parameters	**Higher impacted variable**	**Covariate 1**	**Covariate 2**	**df**	**Std. Error**	**Z value**	***P***
Commercial vs Subsistence Farmer	No difference	Number of respondents implementing non-lethal control techniques	Presence or absence of non-lethal control	13	0.13	0.71	0.480
Presence of non-lethal control vs Absence of non-lethal control	Presence of non-lethal control			13	0.13	2.12	0.034

Discussion

This study set out to identify crop species and livestock/poultry types damaged due to depredation; identify the leading DCAs associated with the greatest number of crop, livestock and poultry depredation incidences; and establish whether these DCAs were common to subsistence and commercial farmers. The findings of this study support the predictions that subsistence farmers lost a greater number of crop species to DCA depredation compared to commercial farmers, and commercial farmers reported implementing a higher number of lethal control practices compared to subsistence farmers.

Crop-raiders

Overall, subsistence farms lost a greater number of crop species to depredation than commercial farmers, with Ndumo localities experiencing the highest numbers of crop species lost when compared with other areas. Although respondents from Mkuze reported high numbers of crop species lost, Mkuze was removed from the statistical analysis because no comparative data for that area was obtained. The findings that subsistence homesteads of Ndumo experienced the highest incidences of crop depredation, corroborated with a previous study in Uganda by Hill (2000) that also showed crop damage in particular may diminish subsistence food production and is, therefore, a threat to the livelihoods of such farmers (Hill, 2000). The Ndumo area was considered a hot spot because this location suffered the highest incidences of crop-raiding in this study, which is of particular concern because these homesteads exist in one of the poorest and most degraded areas of South Africa (Statistics South Africa, 2007). Notably, maize produced by both subsistence and commercial farmers

was the most frequently raided crop. Food security of subsistence households is compromised whenever staple crops such as maize are affected by DCAs (Weladji and Tchamba, 2003) and hence, these findings bear significant ramifications for subsistence livelihoods. In addition, subsistence farmers could be vulnerable to a wider range of crop species loss to depredation because they farm with more heterogeneous crop species. Hence, although there might be a preference for maize by raiders, it is also possible that depredation could be opportunistic or related to availability of crops or proximity of crops from protected area (PA) boundaries, which a more focused study can assess in future.

Primates (the chacma baboon and the vervet monkey) were reportedly responsible for the most crop-raiding incidences, particularly on subsistence farms. According to numerous authorities, terrestrial primate species are more likely to raid and damage crops than arboreal folivorous species (Else, 1991; Hill, 2000; Naughton-Treves, 1998; Sillero-Zubiri and Switzer, 2001; Tweheyo et al., 2005). Several characteristics make primates one of the most successful groups of crop-raiders. Baboons and vervet monkey are able to overcome deterrents such as fencing and scarecrows (Else, 1991; Sillero-Zubiri and Switzer, 2001; Tweheyo et al., 2005) and access food storage vessels that are not accessible to most other wildlife. Primates can quickly learn and recognise new anthropogenic behaviours, such as raiding in the absence of crop guards (Naughton-Treves, 1998; Sillero-Zubiri and Switzer, 2001). Not only are primates highly adaptable to different habitats, they can implement a wide range of feeding strategies and utilise a broad variety of food sources (Sillero-Zubiri and Switzer, 2001; Tweheyo et al., 2005). Furthermore, due to their complex social structures, their cooperative behaviour, their ability to consume food swiftly and to carry additional food away, increases the level of crop damage (Else, 1991; Naughton-Treves, 1998; Sillero-Zubiri and Switzer, 2001; Tweheyo et al., 2005). Hence, primates could potentially raid a large quantity as well as a wide variety of crops during a single raid in a relatively short space of time, as seen in several previous studies (Else, 1991; Naughton-Treves, 1998; Tweheyo et al., 2005), potentially threatening food security. Omnivorous primates like baboon, also show overlap in their dietary requirements with humans, and can depredate a wide range and diversity of human foods, (Kaplan et al., 2011; Sillero-Zubiri and Switzer, 2001) that potentially jeopardise human food security.

Livestock poultry and game depredators

Interestingly, farmer type did not predict the number of livestock/poultry species lost to depredation. However, location differences existed. The predominantly rural areas of

Giyani and Ndumo experienced the highest diversity of livestock/poultry lost to depredation compared with other areas. These areas contain the most vulnerable, low-income human communities in South Africa (Statistics South Africa, 2007; Chapter 4), where low rainfall and acid soils challenge livestock farming (Statistics South Africa, 2007). Hence, these farmers must overcome poor veld grazing conditions (Chapter 4) in addition to frequent depredation of poultry and livestock. Under such conditions, livestock depredation would probably compromise food security in Giyani and Ndumo.

Poultry and young livestock (calves/lambs/kids/foals) were most frequently depredated throughout the study locations. These results were consistent with several other studies; for example, snow leopards in Bhutan preferred smaller livestock and were responsible for the majority of calf and foal mortalities (Sangay and Vernes, 2008). Similarly, in Norway and Sweden, the calves of larger stock species such as bovids and moose *Alces* spp. were more susceptible to bear *Ursus* spp. predation than the adults (Zimmermann et al., 2003). In pastoral areas of South Africa, black-backed jackal depredation of <30-day-old livestock accounted for the majority of livestock losses in five provinces (Van Niekerk, 2010). In the same study, caracals were specifically associated with mortalities of lambs, kids and older small livestock (e.g. goat and sheep) (Van Niekerk, 2010).

Subsistence farmers were affected by a greater diversity of DCAs compared with commercial farmers. These findings were consistent with the results of my meta-analysis of HWC literature (Chapter 2), in which it was shown that local communities living adjacent to PAs were affected by 49 different species of wildlife, the highest diversity of DCAs to affect a group of people in the literature. The wider diversity of DCAs experienced on subsistence farms could be correlated to the practice of mixed livestock and crop farming versus the monoculture farming of commercial farmers seen in the current study.

Caracal, African wild dog, leopard and 'other carnivores' (e.g. bat-eared fox, cheetah, hyena, serval, striped pole cat, genet and wild cat) accounted for the highest number of depredation incidences reported, followed by lion and jackal. My findings that implicated carnivores as significant depredators were consistent with other studies (Schiess-Meier et al., 2007; Thorn et al., 2015). In Botswana, leopard and lion were implicated in the highest number of livestock and game losses reported in the Problem Animal Control Register from the Kweneng District over a three-year period (Schiess-Meier et al., 2007). This is consistent with survey reports in the present study, where lions in particular were perceived as a threat to human safety due to frequent PA boundary transgressions. Schiess-Meier et al., (2007) hypothesised that, along PA boundaries, lion could quickly learn to hunt livestock

sporadically in nearby farms (Schiess-Meier et al., 2007), supporting the reports from survey respondents in my study.

Large-bodied carnivores are naturally built for ungulate predation (Treves and Karanth, 2003). Hence, these predators were highly likely to kill domestic ungulates if and when the opportunity arises (Potgieter et al., 2015; Treves and Karanth, 2003). In the Machiara National Park, Pakistan, leopard was the leading depredators of goat and sheep, accounting for ~91% of livestock losses (Dar et al., 2009). Similarly, other human-carnivore conflict studies conducted in Bhutan and Pakistan reported leopard as the primary livestock predator (Sangay and Vernes, 2008; Wang and Macdonald, 2006). As with primates, leopard possess a number of biological characteristics that render them high-impact conflict species (Kissui, 2008; Marker and Dickman, 2005; Woodroffe, 2000). Leopard occupy a wide array of habitats and are widely distributed throughout Africa, Asia and the Middle East (Kissui, 2008; Mizutani and Jewell, 1998). Due to their cryptic nature, they adapt better than other large predators to anthropogenic-dominated landscapes (Di Minin et al., 2016; Nowell and Jackson, 1996). Importantly, leopard display significant behavioural plasticity (Marker and Dickman, 2005; Dickman, 2008) in their activity patterns and prey selection that enable them to adapt to a range of ecological settings (Woodroffe, 2000), including anthropogenic settings (Marker and Dickman, 2005; Dickman, 2008; Woodroffe, 2000).

The African wild dog, caracal and jackal were the other leading carnivores frequently depredating livestock and game. These results were also consistent with several other southern African studies that associated these species with allegedly high incidences of livestock depredation (Avenant and Du Plessis, 2008; Gusset et al., 2009; Van Niekerk, 2010). Interestingly, Woodroffe et al., (2005) showed that the endangered African wild dog only killed livestock when their natural prey species were extremely scarce. My findings corroborated those of another questionnaire survey conducted in the North West Province of South Africa that reported the black-backed jackal and caracal to be the leading pest species associated with livestock depredations (Thorn et al., 2012). Some scholars suggest that these predators select livestock opportunistically, especially when natural prey is depleted or during periods of high metabolic activity such as pregnancy and lactation (Avenant and Nel, 2002; Kamler et al., 2012).

Commercial farmers (game and livestock) incurred greater financial losses due to depredation compared with subsistence farmers. This could be attributed to the expensive unit price of livestock and game species that is regulated by the Livestock Trader organisation and the Game Ranchers' Association. These results were in line with several

other studies (Thorn et al., 2015; Treves and Karanth, 2003; Van Niekerk, 2010; Woodroffe et al., 2005) that report significant monetary losses to the commercial livestock industry due to depredation. However, there is conflicting reports over financial losses incurred by commercial farmers in South Africa (McManus et al., 2014). Some studies (Treves and Karanth, 2003; Van Niekerk, 2010; Woodroffe et al., 2005) suggest that livestock predation can potentially jeopardise commercial farming livelihoods, while others show minor losses to commercial game and livestock holdings (McManus et al., 2014; Thorn et al., 2012).

Farmer retaliation, lethal control and persecution of wildlife

Predictably, commercial farmers comprised the greater number of respondents who practised retaliation, with shooting and poisoning being the leading methods of retaliation. These findings concur with other studies in South Africa and Zimbabwe, in which commercial cattle farmers were intolerant of large mammalian carnivores (Lindsey et al., 2005). Importantly, farmed game species often occur in small populations, especially exotic game species, and are expensive to replace (Marker and Schumann, 1998), thus attracting low wildlife tolerance from commercial game farmers (Schumann et al., 2008).

Carnivores appeared prominently in the reports of persecutory killings of wildlife, especially the leopard. The chacma baboon and the vervet monkey were commonly persecuted on subsistence farms, with similar numbers of mortality due to persecution as other perceived damage-causing carnivores, such as the leopard. Similarly, Macdonald et al., (2012) showed through a global meta-analysis that the overall threats facing felids and primates were often the same and often occur in the same place. My results regarding carnivore persecution were also supported by findings of Woodroffe and Ginsberg (1998) and Dickman (2010), both of whom demonstrated that free-ranging carnivores in developing countries were often in conflict with rural communities, commercial farmers and game ranchers, and the lethal control of these carnivores in response were common (Dickman, 2010; Swanepoel et al., 2014; Treves and Karanth, 2003; Woodroffe and Ginsberg, 1998). In South Africa, as in other parts of Africa, repercussions of carnivore persecution have particularly important implications for the persistence of endangered species such as African wild dog (Woodroffe and Ginsberg, 1998) and the vulnerable leopard (Swanepoel et al., 2014), that are free-ranging and frequently inhabit agricultural landscapes (Mills and Gorman, 1997). Authorities also postulate that DCAs are likely to thrive along the PA edges of indigenous habitat and farms where they can access both natural food from the PAs and crops and livestock/poultry from the adjacent farms (Naughton-Treves, 1998; Sillero-Zubiri

and Switzer, 2001). The map illustrating the distribution of animals reportedly killed by respondents, indicated that carnivores were targeted in the Waterberg area, Limpopo Province, while primates, rodents and reptiles were more commonly persecuted in KwaZulu-Natal Province. However, for a valid comparison to be made, subsistence and commercial farmers who operate with multi-crop commodities (De Klerk, 2003) need to be interviewed in the Waterberg, to elucidate whether primates and rodents present any depredation threats and importantly whether they are targeted by such farmers with lethal control.

Non-lethal control

Farmer type did not predict non-lethal control. However, the prevalence of non-lethal control outweighed its absence. Several forms of non-lethal control were practised in my study and in the literature (Macdonald et al., 2012; Osborn and Parker, 2003). A large number of respondents in my study claimed to implement non-harmful techniques to protect their farm holdings, which is promising for mitigation efforts; for example, non-lethal control practices such as field guarding have been shown to reduce crop-raids by 85% (Osborn and Parker, 2003) and potentially present a reduced threat to wildlife.

Conclusions

Subsistence farmers were associated with the greatest diversity of crop species lost, and although farmer type did not influence livestock/poultry depredation, areas of greater than average livestock depredation were identified in two rural areas of the Limpopo and KwaZulu-Natal Provinces. I also established that maize, poultry and young livestock, important staple food security commodities, were most frequently lost to wildlife depredation. Consistent with the findings of other studies that examined commercial farmer-carnivore conflict, my findings showed that commercial game farmers comprised a significant number of respondents who reported lethal control of carnivores. Furthermore, mine is the first study to provide comparative data (that subsistence farmers were outweighed by lethal controlling commercial ranchers) of how people from different economic classes managed problem animals. Hence, wildlife depredation and persecution are the products of socioeconomic and ecological issues, which are controversial because the farming resources damaged bear implications for human livelihoods, and the conservation species concerned are vulnerable. For example, the African wild dog and leopard, perceived as leading damage-

causing carnivores in this study, are conservation priority species and are protected by legislation (Anthony, 2007; IUCN, 2012), and the repercussions of perceived damage-causing notoriety therefore have particularly important consequences for the survival of such endangered species. It would also be interesting to generate a species of conservation concern hot spot analysis in future, with more detailed focused GIS analyses (incorporating landscape criteria like proximity to PAs, land-use layers and distribution of natural resources) looking at the complexities and causes of greater than average livestock and crop depredation in certain areas. The identification of such hot spots would help inform landscape mitigation schemes to diminish HWC in the areas where such mitigation is most needed. Future research should also investigate the attitudes and perceptions of subsistence and commercial farmers that can determine farmer tolerance to wildlife and ultimately contribute towards a conflict mitigation plan.

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Supplementary material

Table S1. Livestock, poultry and game loss for both subsistence and commercial farmers at each location. Damages due to depredation are expressed in South African Rands (ZAR); R0.00 indicates no damages were incurred for this species.

Type of livestock, game or poultry damaged	**Species name**	**Unit price** (average price derived from 2013 Game Ranchers' Association and Livestock Trader)	**Giyani Commercial**	**Giyani Subsistence**	**Waterberg Commercial**	**Komatipoort Commercial**	**Komatipoort Subsistence**	**Ndumo Commercial**	**Ndumo Subsistence**
Blesbuck	*Damaliscus pygargus phillipsi*	R 2 839	R0.00	R0.00	R 110 721	R0.00	R0.00	R0.00	R0.00
Buffalo (Cape)	*Syncerus caffer*	R 30 882	R0.00	R0.00	R 30 882	R0.00	R0.00	R0.00	R0.00
Bushbuck	*Tragelaphus sylvaticus*	R 9 878	R0.00	R0.00	R 49 390	R0.00	R0.00	R0.00	R0.00
Calves/ lambs	*Bos taurus/ Ovis aries*	R 5 000	R 65 000	R0.00	R 1 370 000	R0.00	R0.00	R0.00	R0.00
Cattle	*Bos taurus*	R 5 000	R 125 000	R 355 000	R 80 000	R0.00	R0.00	R0.00	R0.00
Common reedbuck	*Redunca arundinum*	R 7 299	R0.00	R0.00	R 7 299	R0.00	R0.00	R0.00	R0.00
Duiker	*Sylvicapra grimmia*	R 3 831	R0.00	R0.00	R 30 648	R0.00	R0.00	R0.00	R0.00
Eland	*Tragelaphus oryx*	R 7 097	R0.00	R0.00	R 63 873	R0.00	R0.00	R0.00	R0.00
Gemsbok	*Oryx gazella*	R 6 172	R0.00	R0.00	R 12 344	R0.00	R0.00	R0.00	R0.00
Giraffe	*Giraffa camelopardalis*	R 14 846	R0.00	R0.00	R 44 538	R0.00	R0.00	R0.00	R0.00
Goat	*Capra aegagrus hircus*	R 1 000	R0.00	R 1 000	R 32 000	R 1 000	R0.00	R0.00	R 28 000
Hartebeest	*Alcelaphus buselaphus*	R 4 663	R0.00	R0.00	R 79 271	R0.00	R0.00	R0.00	R0.00
Horse/donkey	*Equus ferus caballus*	R 10 000	R0.00	R 40 000	R 20 000	R0.00	R0.00	R0.00	R0.00
Impala	*Aepyceros melampus*	R 1 283	R0.00	R0.00	R 473 427	R0.00	R0.00	R0.00	R0.00
Klipspringer	*Oreotragus oreotragus*	R 10 000	R0.00	R0.00	R 10 000	R0.00	R0.00	R0.00	R0.00
Kudu	*Tragelaphus strepsiceros*	R 6 646	R0.00	R0.00	R 312 362	R0.00	R0.00	R0.00	R0.00
Nyala	*Tragelaphus angasii*	R 10 706	R0.00	R0.00	R 535 300	R0.00	R0.00	R0.00	R0.00
Ostrich	*Struthio camelus*	R 2 031	R0.00	R0.00	R 8 124	R0.00	R0.00	R0.00	R0.00
Poultry		R 80	R0.00	R 1 200.00	R0.00	R0.00	R 720	R0.00	R 18 160

Type of livestock, game or poultry damaged	**Species name**	**Unit price** (average price derived from 2013 Game Ranchers' Association and Livestock Trader)	**Giyani Commercial**	**Giyani Subsistence**	**Waterberg Commercial**	**Komatipoort Commercial**	**Komatipoort Subsistence**	**Ndumo Commercial**	**Ndumo Subsistence**
Sable	*Martes zibellina*	R 294 947	R0.00	R0.00	R 294 947	R0.00	R0.00	R0.00	R0.00
Sheep	*Ovis aries*	R 1 250	R0.00	R0.00	R 31 250	R0.00	R0.00	R0.00	R0.00
Steenbok	*Raphicerus campestris*	R 6 565	R0.00	R0.00	R 39 390	R0.00	R0.00	R0.00	R0.00
Tsessebe	*Damaliscus lunatus lunatus*	R 13 959	R0.00	R0.00	R 41 877	R0.00	R0.00	R0.00	R0.00
Warthog	*Phacochoerus* sp.	R 456	R0.00	R0.00	R 13 224	R0.00	R0.00	R0.00	R0.00
Waterbuck	*Kobus ellipsiprymnus*	R 3 846	R0.00	R0.00	R 69 228	R0.00	R0.00	R0.00	R0.00
Wildebeest	*Connochaetes taurinus*	R 2 941	R0.00	R0.00	R 82 348	R0.00	R0.00	R0.00	R0.00
Zebra	*Equus zebra*	R 4 975	R0.00	R0.00	R 39 800	R0.00	R0.00	R0.00	R0.00
Total damage per location		**R 4 373 063**	R 190 000	R 397 200	R 3 737 983	R 1 000	R 720	R0.00	R 46 160

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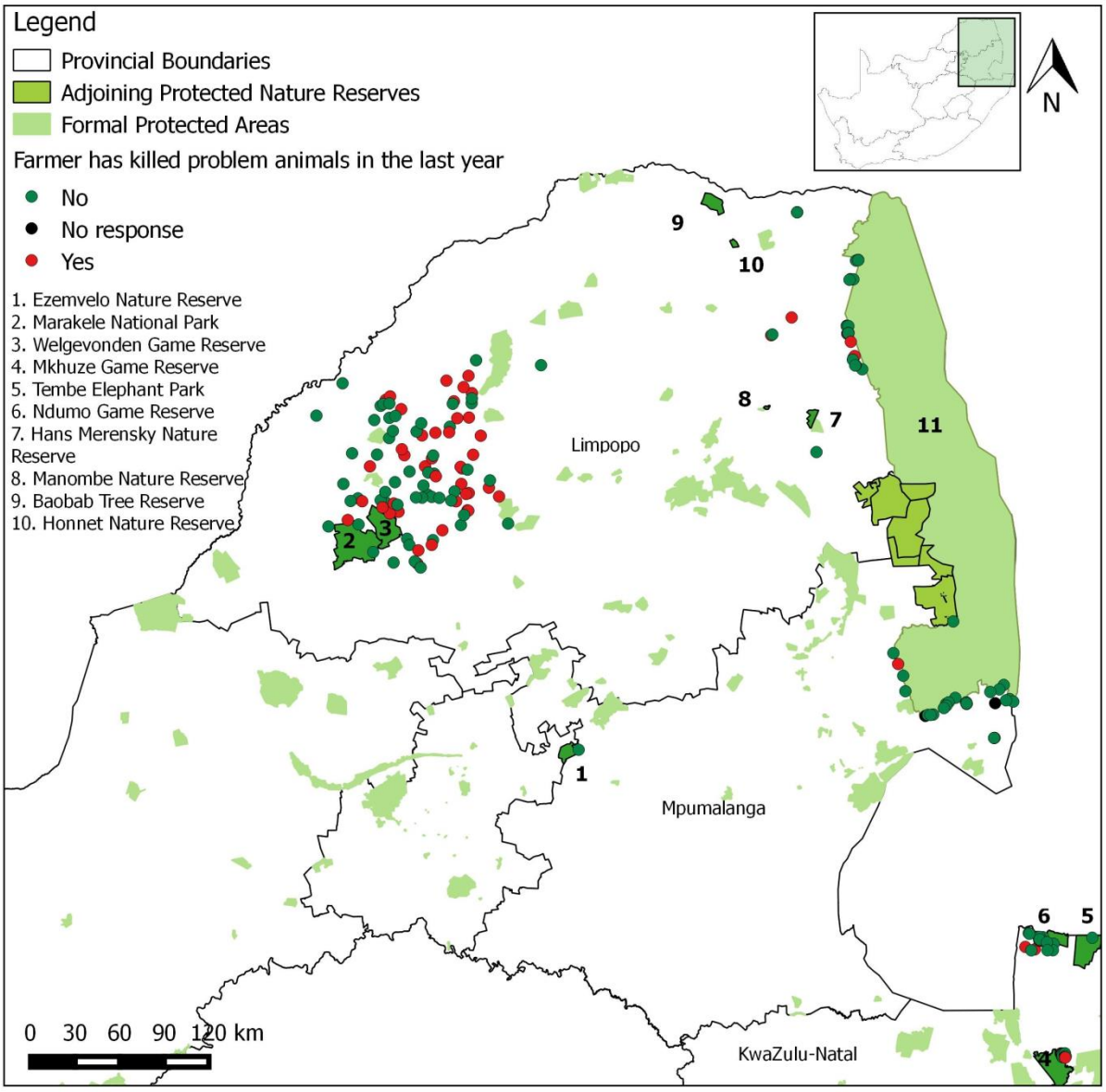


Figure S1. Spatial distribution of farmers that reportedly killed a problem animal during 2013–2014. Red global positioning system data points represent the location of farmers who reported implementing lethal control, while green global positioning system points represent farmers who reported they did not use lethal control. A full description of the different coloured global positioning system points is provided in the map legend. Numbers represent key protected areas. Number 11 denotes the Kruger National Park. A map of South Africa is provided in the inset.

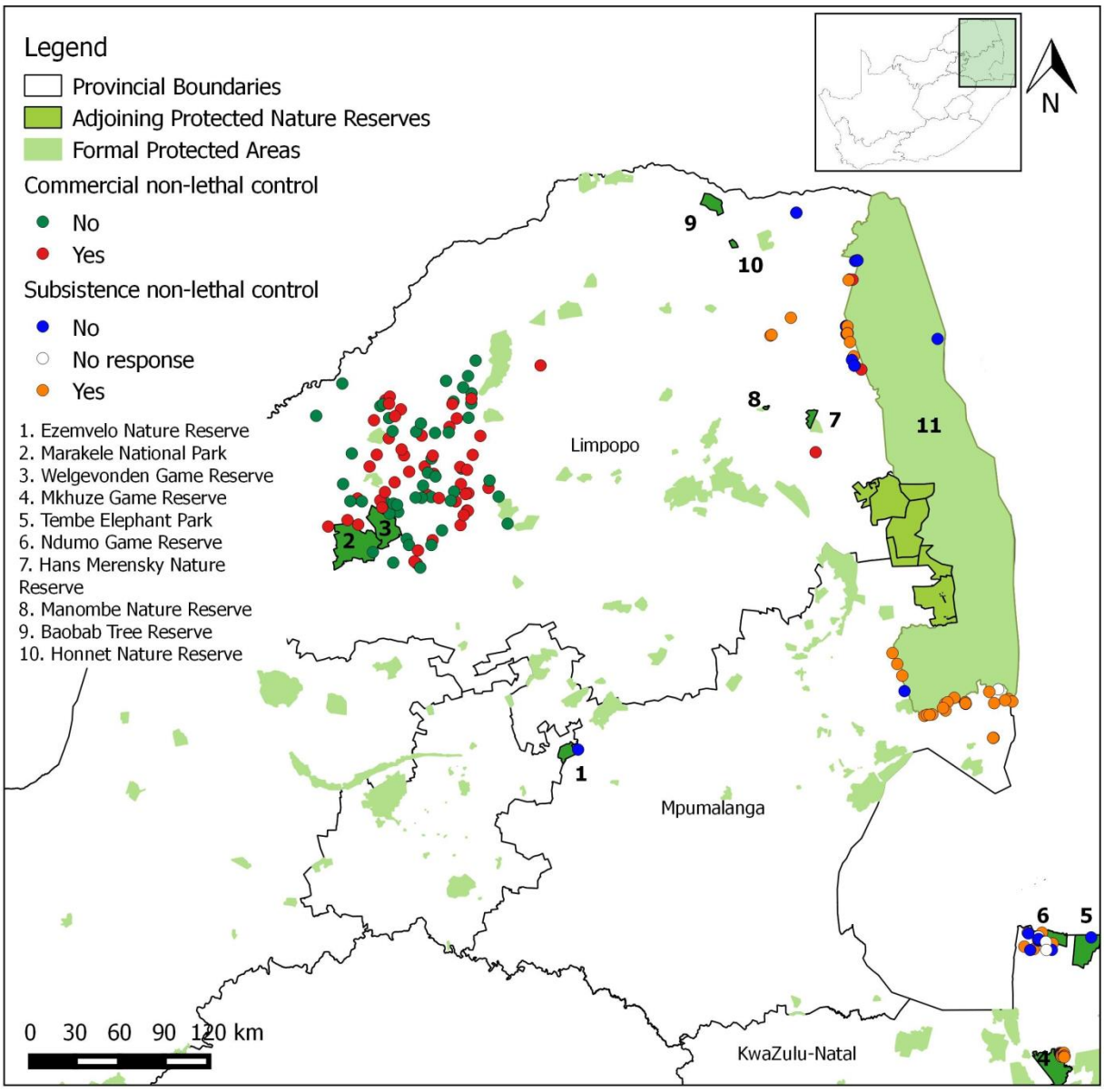


Figure S2. Spatial distribution of subsistence and commercial farmers who reported using non-lethal control methods to protect their crops and/or livestock/ poultry/game against problem animals. Coloured global positioning system data points represent the location of farmers, and a full description of the different coloured global positioning system points is provided in the map legend. Numbers represent key protected areas, where number 11 denotes the Kruger National Park. A map of South Africa is provided in the inset.

CHAPTER SIX

Attitudes and opinions of subsistence and commercial farmers towards wildlife in north-eastern South Africa

Abstract

The attitudes of farmers and local communities towards biodiversity and conservation issues are increasingly being considered in the management of protected areas. I evaluated the attitudes and opinions of subsistence and commercial farmers towards wildlife, using semi-structured questionnaire interviews and a geographic information system attitude index (a method to visualise the spatial distribution of subsistence and commercial farmers' attitudes) on farmland bordering protected areas in north-eastern South Africa. There were no differences in the attitudes between subsistence and commercial farmers, with the exception that subsistence farmers demonstrated a significantly higher percentage of agreement to the statement 'Wildlife should be kept only in fenced-off areas'. Collectively, positive attitudes accounted for seven of the 13 statements relating to ecocentric attributes (concern for the ecosystem) such as environmental education, tourism and a willingness to learn about non-harmful wildlife control. Overall, farmers were negative towards six of the 13 statements, showing a low-tolerance for resource damage, crop and livestock in particular. A third of the respondents (38%) indicated that they elicited help with human-wildlife conflict-related problems, citing the need for conservation authorities to assist with "better fencing", "better compensation" and "more communication". Interestingly, high negative and high positive geographic information system data points overlapped in the same geographic areas of Giyani and Ndumo, rural areas of the Limpopo and KwaZulu-Natal Provinces for both subsistence and commercial farmers. This indicates that attitudes of people often vary significantly depending on the individual's experiences, values and beliefs. It appears that subsistence and commercial farmers hold positive and negative attitudes towards wildlife, possibly for different reasons. For example, although some positive attitudes of subsistence and commercial farmers were related to the aesthetic and economic value of wildlife, subsistence farmers could be motivated by employment prospects through ecotourism due to their lower income than commercial farmers. Hence, a specific set of variables and typologies predicted the attitudes and opinions of farmers towards wildlife. Overall, positive attitudes

related to employment prospects, tourism revenue and the potential for mentorship through environmental education. Negative attitudes and opinions related to free-ranging and stray wildlife (individuals that transgress protected area boundaries), the negative potential of wild animals to damage farming resources and the lack of communication with conservation authorities.

Keywords: commercial farmers, geographic information system attitude index, negative attitudes, positive attitudes, South Africa, subsistence farmers

Introduction

Incidences of wildlife depredation of farming resources, such as crop and livestock, or threats to the safety of people due to possible injury by wildlife often lead to the persecution of wild animals (Graham et al., 2005). The combined influence of human persecution of wildlife (DeGeorges and Reilly, 2008) and the spread of zoonotic diseases (MacKenzie, 1997) prompted conservation authorities together with governments to establish conservation areas and game parks to protect biodiversity and the ecological resources within their borders, resulting in the restriction of other land uses (Bruner et al., 2001). Consequently, for farmers living alongside conservation areas of parks, resource use in the park is restricted, while encounters with potential damage-causing animals (DCAs) are increased (DeGeorges and Reilly, 2008; Treves et al., 2006), thus promoting negative sentiments between park authorities and local human communities in the human-wildlife conflict (HWC) quandary. In addition, inadequate or lack of compensation for losses related to wildlife depredation increases antagonism towards biodiversity (Treves et al., 2006).

The attitudes of farmers and local communities towards biodiversity and conservation are gradually being considered in the management of protected areas (PAs) (Alexander et al., 2015; Anthony, 2007). The deliberate killings of wild animals are underpinned by negative attitudes and opinions of people towards perceived DCAs worldwide. These attitudes have led to active persecution of wild animals, ranging from sporadic poisoning to government-driven extirpations (Barnes, 1996; Naughton-Treves, 1997; Woodroffe, 2000), even outside PAs (Lindsey et al., 2005; Olsen et al., 2014; Woodroffe and Ginsberg, 1999). Therefore, future conservation efforts depend on understanding and considering the attitudes and opinions of people towards wildlife in conjunction with identifying problem animals and levels of damage.

Wildlife transgressing PA boundaries is a global problem and a concern for local human communities and PA managers (Hussain, 2003; Jackson and Wangchuck, 2001). Fragmentation of PAs by impinging local communities have had particularly adverse effects on wide-ranging wildlife which require large ranges (area where all the resources the animal requires to survive and reproduce is contained; Woodroffe and Ginsberg, 1998), by reducing home-range size and PA effectiveness (Mills et al., 1998; Woodroffe and Ginsberg, 1998). In addition, encroachment by local communities upon PAs has been shown to increase contact between wildlife and anthropogenic activity on PA borders, areas where high human-induced wildlife mortality can be expected due to conflict. In the Hemis National Park in India, local subsistence farmers increased the retaliatory killings of the snow leopard *Uncia uncia* and Indian wolf *Canis lupus pallipes* in response to livestock raids and because of a deterioration of communication between conservation authorities and local communities (Jackson and Wangchuck, 2001). Similarly, subsistence farmers in the Indian Himalayas harboured extremely negative attitudes towards the snow leopard due to the hardships the community suffered from acts of domestic stock depredation that threatened their livelihoods (Mishra et al., 2003). Dickman (2010) showed that subsistence farmers in Tanzania were particularly hostile and antagonistic towards wildlife since the potential consequences of depredation of farming stock would be intensified by the lack of alternate income.

Madden (2004) hypothesised that HWC commonly involves characteristically impoverished human communities, historically disenfranchised and culturally misunderstood, with shortfalls in trust and communication with conservation authorities regarding how to conserve biodiversity and ensure the livelihoods of people simultaneously. South Africa provides the ideal setting to test the Madden (2004) hypothesis because subsistence farmers living in poverty are compressed into degraded land on the edge of PAs, alongside commercial farms in the same geographical areas (Armstrong et al., 2008; Khan, 1994).

Since the 16th century, wildlife in Africa has been a source for European conquest (DeGeorges and Reilly, 2008) of ivory and pelts, whilst colonialists expropriated land for precious minerals, cash-crop plantations and forest products to feed colonial capitalism (Keller and Golley, 2000). Consequently, indigenous black Africans were dispossessed and alienated from the land they occupied (DeGeorges and Reilly, 2008; Khan, 1994). Imperial powers excluded African traditional beliefs (Keller and Golley, 2000) of sustainable, indigenous resource-management strategies in favour of biblical tenets to manage wildlife (Carruthers, 1995; DeGeorges and Reilly, 2008; Keller and Golley, 2000). These religious doctrines maintained that humans had the right to exploit natural resources as desired

(DeGeorges and Reilly, 2008). Moreover, European settlers acquired from colonial governments the most fertile land in attractive farming climates for agriculture (DeGeorges and Reilly, 2008), while Africans were secluded to overcrowded and land-degraded settlements (Cock and Fig, 2000; DeGeorges and Reilly, 2008).

No efforts were made to conserve ecological resources until the late 19th century (DeGeorges and Reilly, 2008), which corresponded with rinderpest outbreaks that nearly eliminated most wild ungulates in Sub-Saharan Africa (MacKenzie, 1997). Thus, hastened efforts that excluded Africans (Cock and Fig, 2000) to shape conservation legislation and establish PAs, such as nature reserves and game parks, were made. A protectionist philosophy emerged that perceived indigenous people as inept in managing wildlife (Cock and Fig, 2000), branding subsistence on wildlife as a mechanism to elude waged labour (Carruthers, 1995). Colonial powers in government completely overlooked the co-evolution of indigenous people and wildlife in Africa where the sustainable use of natural resources occurred for approximately 10 centuries (DeGeorges and Reilly, 2008; Keller and Golley, 2000).

A large number of indigenous people were evicted throughout Africa to accommodate the establishment of PAs (Cock and Fig, 2000; DeGeorges and Reilly, 2008) and were compressed into impoverished communities that bordered PAs (Anthony, 2007). For example, in the early 1900s, approximately 3 000 people were evicted from their settlements and lost their grazing pastures in order to establish the Kruger National Park (KNP) (Carruthers, 1995). Hence, historical political issues such as racial segregation and discriminatory laws have influenced present day perceptions of wildlife and the environment by Africans (Khan, 1994).

In Sub-Saharan Africa, recent studies show that negative attitudes towards wildlife exist among commercial (Parker et al., 2014; Lindsey et al., 2005) and subsistence (Gusset et al., 2008) farmers, especially towards carnivores (Parker et al., 2014, Gusset et al., 2008; Marker et al., 2003). In addition, negative attitudes of local communities in Limpopo Province, South Africa were associated with inadequate maintenance of PA perimeter fences, poor problem-animal control outside the park and lack of compensation for depredation (Anthony, 2007). Infield (1988) and Newmark et al., (1993) showed that diminished household wealth negatively influenced attitudes towards wildlife in KwaZulu-Natal Province, South Africa and in Tanzania. Furthermore, tensions between local communities and PA authorities globally are intensified by poor communication, lack of interaction with

communities and inadequate financial compensation for HWC damages (Dickman, 2010; Jackson and Wangchuck, 2001).

Although HWC has been widely researched in South Africa, I am not aware of any studies that directly compare or evaluate the attitudes and opinions towards wildlife of subsistence and commercial farmers who are farming in the same geographic areas. Moreover, only few studies are known about the current attitudes and opinions towards wild animals of rural subsistence households in South Africa (Parker et al., 2014; Lindsey et al., 2005), a politically marginalised and economically vulnerable group of people (DeGeorges and Reilly, 2008; Khan, 1994). My study was conducted in three impoverished provinces in South Africa, where subsistence and commercial agriculture occur concurrently, namely the Limpopo, Mpumalanga and KwaZulu-Natal provinces, which are located in the north-eastern areas of South Africa.

The aim of the study was to evaluate the attitudes and opinions of subsistence and commercial farmers towards wildlife and conservation issues using semi-structured questionnaire interviews and a geographic information system (GIS) attitude index (discussed later) in selected localities of north-eastern South Africa (Fig. 1). Notably, factors affecting people's attitudes and opinions towards wildlife are complex, and some variables are more difficult to quantify and investigate than others (Kellert, 1993). I therefore provide clear definitions to distinguish attitudes from opinions. I define: (i) attitude as the manner, disposition, feeling or position of subsistence and commercial farmers towards wild animals; and (ii) opinion as a belief or judgement by farmers. I reported the opinions as illustrated quotes in my results (below). Two key questions were posed in this study. 1) Since both subsistence and commercial farmers can experience HWC with wildlife, do both hold negative attitudes to wildlife? 2) Do subsistence and commercial farmers hold positive, negative or neutral attitudes towards wildlife?

Materials and methods

Data for this chapter were extracted from survey responses to the questionnaire in Chapter 3 (Appendix I), and detailed general methodology concerning study site, data collection, the framework of the questionnaire, sampling procedures and interview methods is provided in Chapter 3. The study was conducted in north-eastern South Africa at selected agri-pastoral localities (Fig. 1; Table 1) within the provinces of KwaZulu-Natal, Mpumalanga and Limpopo. In total, 128 farmers from the Giyani, Komatipoort and Ndumo areas

participated in the questionnaire (n = 18 commercial farmers, n = 110 subsistence farmers) (Table 2). Farmers from the Mkuze and the Waterberg areas did not participate in this segment of the survey.

Table 1. Sites in north-eastern South Africa where selected localities within the provinces of Kwa-Zulu Natal, Mpumalanga and Limpopo were sampled. The type of farmer sampled at each site is provided with the associated protected area.

Province	Study site	Protected area	Type of farmer
Limpopo	Giyani	Kruger National park, Manomba Nature Reserve	Subsistence and commercial farmer
Mpumalanga	Komatipoort	Kruger National park, Marloth Park	Subsistence and commercial farmer
KwaZulu-Natal	Ndumo	Tembe and Ndumo game reserves	Subsistence and commercial farmer

Table 2. The type and number of farmers interviewed at each site and the total number of questionnaire interviews conducted.

Province	Locality	Number of surveys per site	Subsistence farmer	Commercial farmer
Limpopo	Giyani	41	30	11
Mpumalanga	Komatipoort	33	28	5
KwaZulu-Natal	Ndumo	54	52	2
Total farmer surveys		**128**	**110**	**18**

Assessing attitudes towards wildlife

Gauging the attitudes and opinions of people towards wildlife is difficult because these often vary significantly from person to person depending on individual experiences, culture and religion, as well as influences from friends, family, the community and social media (Kellert, 1993). The questionnaire in Chapter 3 (Appendix 1) made provision to evaluate a variety of typologies (Kellert, 1993) (Table 3) by allowing for trichotomous responses such as agree, disagree and unsure or yes, no and unsure/no response, as suggested by Lindsey et al., (2005) and White et al., (2005). In addition, responses to open-ended questions provided opportunities for non-prescriptive responses. Respondents were asked to give their view on a number of statements (Table 4) by selecting the one that suited best (agree, disagree or unsure). Consequently, an association with the dominant typology was distinguished for each statement (Table 4). The responses enabled me to gauge if the attitudes and opinions of farmers were positive, negative or neutral towards wildlife and to construct a GIS attitude index.

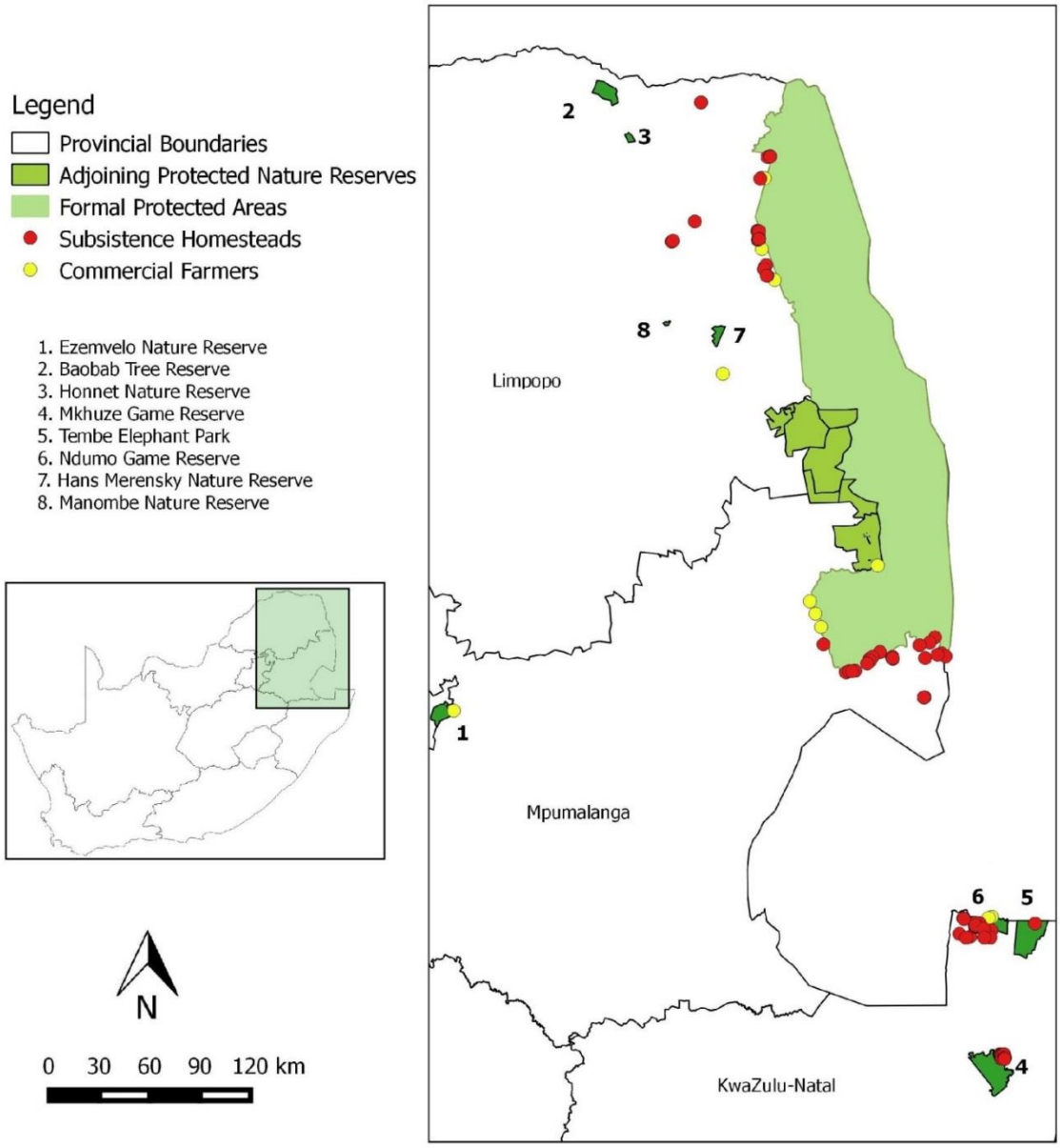


Figure 1. Location of subsistence homesteads and commercial farms surveyed in north-eastern South Africa. Major protected areas displayed only. Red and yellow circles are global positioning system data points that indicate the location of subsistence homesteads and commercial farmers respectively. Numbers indicate key protected areas. A map of South Africa is provided in the inset.

Table 3. Typologies developed to evaluate the attitudes and opinions of subsistence and commercial farmers, using guidelines proposed by Kellert (1993).

Typology	Description
A	The aesthetic and economic value of wildlife
B	Damage-causing ability and the negative potential of wild animals to depredate on farming resources
C	The moralistic and humanistic interests of respondents
D	The utilitarian personalities of people that dictate the use of lethal or non-lethal retaliatory practices in dealing with HWC
E	Concern for the ecosystem and the relationships between wildlife and natural habitats

Geographic information system attitude index

In addition to the attitude typologies, I used a GIS attitude index for visualising the spatial distribution of subsistence and commercial farmer attitudes to categorical questions (positive, negative or neutral) without data analysis or the generation of *P*-values (Page et al., 2015). While the GLMM examined distinctions between farmer type and their responses (and did not consider location differences), the GIS attitude index provides a geographic distribution of attitudes. A Poisson error structure with a log link function was used for count data throughout the generalised linear mixed model (GLMM) analysis, except for binary data, in which case binomial distribution was used with the log link function, because continuous responses could be exaggerated. Responses to statements 1 to 13 in Table 4 were assigned values to generate GIS attitude index scores (Page et al., 2015). Open-ended questions (statements 14 to 15) could not be assigned index scores.

Table 4. Statements used in the assessment of attitudes (Statements 1−12) and opinions (Statements 13−15) and the different typologies associated with each attitude.

Statements/Questions	**Typology**
1. There are good things about wild animals	A or B
2. Wild animals bring tourists, and this is good for our community/farm	A or B
3. I want to learn more about environmental education	E
4. I want to see fewer wild animals in this village	B or E
5. Problem animals cost me money	B or E
6. Problem animals are pests and take far more than they need	B or E
7. Animals are God's creation, and we must not harm them	B or C
8. I want to learn more about non-harmful ways to keep wild animals away	B or E
9. Wildlife should be kept only in fenced-off areas	B or E
10. It does not matter if wild animals kill a few of my animals / destroy some of my crops	D or E
11. If you remove/kill a problem animal, another one will return	D or E
12. Killing problem animals is cheaper than protecting my crops/stock in other ways	D or E
Opinion on free-ranging wildlife	
13. Are there any wild animals that you would like to see on your village/farm?	B or E
Opinions regarding conservation authorities (presented as illustrated quotes)	
14. Did you ask conservation authorities for help with the problem animal?	
15. How would you like people working for Parks to help you?	

I adopted the more recent protocols implemented by Page et al., (2015) and Anthony (2007) to generate index scores. These protocols were used to successfully evaluate attitudes

and opinions of rural communities towards wildlife in South Africa specifically, and these authorities have published their studies in ISI-indexed journals. Index scores were calculated by allocating values of between +2 and -2 to the questions according to a strongly positive (+2), positive (+1), neutral (0), negative (-1) or strongly negative (-2) response towards wildlife or people. For example, for the statement, 'There are good things about wild animals', a score of +2 was given if the respondent strongly agreed (indicating strongly positive attitudes), +1 if the respondent agreed, 0 if the respondent was unsure or gave no response, -1 if the respondent disagreed and -2 if the respondent strongly disagreed (indicating strongly negative attitudes). For the evaluation of Question 13, 'Are there any wild animals that you would like to see on your village/farm', only a 'yes', 'no' or 'I don't know/no' response could be elicited, and the evaluation, therefore, carried a maximum value of 1 not 2 for this question. In Question 13, a 'yes' response (positive response) was allocated +1, a 'no' response (negative response) was allocated -1 and an 'I don't know/no' response (neutral) was given 0. The sum of all the scores was calculated for each farm type (subsistence, commercial) per locality for all questions (12 responses plus opinion on free-ranging wildlife per interview (Question 13) (**Supplementary material:** Table S3). Hence, the maximum value that could be achieved for the attitude index of subsistence and commercial farmers was +25, which would indicate very positive attitudes towards wildlife in the area, while -25, the maximum negative value, would indicate a respondent who had very negative attitudes towards wildlife.

The attitude index for each respondent was subsequently displayed as a map using Quantum GIS (QGis) 2.8.1 (see GIS analysis in Chapter 3). Representing these data geographically enabled me to highlight areas of low concern in which predominantly positive attitudes exist and areas of high concern in which largely negative attitudes were prevalent. Although Page et al., (2015) proposed that the more negative the attitude index, the greater the potential threat to the persistence of wildlife within that area, I maintain that positive attitudes might provide the foundation for future collaborations between farmers and conservation authorities, while negative attitudes might not.

Data analysis

Detailed quantitative statistical analysis methodology is provided in Chapter 3. Descriptive qualitative summaries for reporting statistics concerning percentages of opinions expressed by respondents are also presented.

To evaluate the outcome of responses (negative, positive or neutral) and the dominant typology associated with each statement, I individually analysed the responses for each statement in Table 4. The result of each statement addressed two sub-questions: (i) Do subsistence and commercial farmers' responses differ from each other; and (ii) which response is dominant for each question? (E.g. Are the number of 'agree' responses significantly more than the number of 'disagree' responses?) Depending on the statement and dominant responses, I evaluated whether the outcome was negative, positive or neutral towards wildlife and assigned a typology associated with either potential for threats or co-existence between humans and wildlife.

To compensate for unbalanced sampling of subsistence and commercial farmers, I examined the number of agree, disagree or unsure responses over the total number of commercial or subsistence farmers sampled to produce a percentage of responses for subsistence and commercial farmers separately. The percentages of agree, disagree and unsure responses (dependent factors) produced by subsistence and commercial farmers (fixed factors) for each question were analysed using a GLMM.

Geographic information system map constructions

Detailed GIS methodology is provided in Chapter 3. Separate maps were produced to display geographically: (i) the distribution of subsistence and commercial farmers interviewed; and (ii) a GIS attitude index for subsistence and commercial farmers.

Results

Attitudes of farmers towards wildlife

Farmer type did not predict attitudes in response to most statements (Table 5), except for Statement 9 in which subsistence farmers more frequently agreed that 'Wildlife should be kept only in fenced-off areas' (Fig. 2; Table 6a-b). In addition, I found that differences between types of responses existed (Table 5); a positive outcome predominated in seven of the 13 statements (irrespective of farmer type) (Table 5). The output of the generalised linear mixed model by maximum likelihood, comparing subsistence and commercial farmer responses as well as the comparison of trichotomous responses, is included in **Supplementary material:** Tables S1 and S2 respectively. Typology B, damage-causing ability and negative potential of wild animals, was associated with five of the 13 statements,

while Typology E, ecocentric values, was associated with four of the 13 statements (Table 5). The remaining statements were associated with Typology A, aesthetic and economic values (two statements), Typology C, moralistic and humanistic interests (one statement) and Typology D, utilitarian values (one statement).

The GLMM examined differences between farmer type and their responses (but did not consider location differences for these investigations), while the GIS attitude index provides a geographic distribution of farmer attitudes.

In response to 'Wildlife should be kept only in fenced-off areas', 'agree' responses dominated over 'unsure' and 'disagree' responses (Fig. 2; Table 6b). This is a negative outcome for wildlife since the responses showed low tolerance for free-ranging wild animals by both subsistence and commercial farmers.

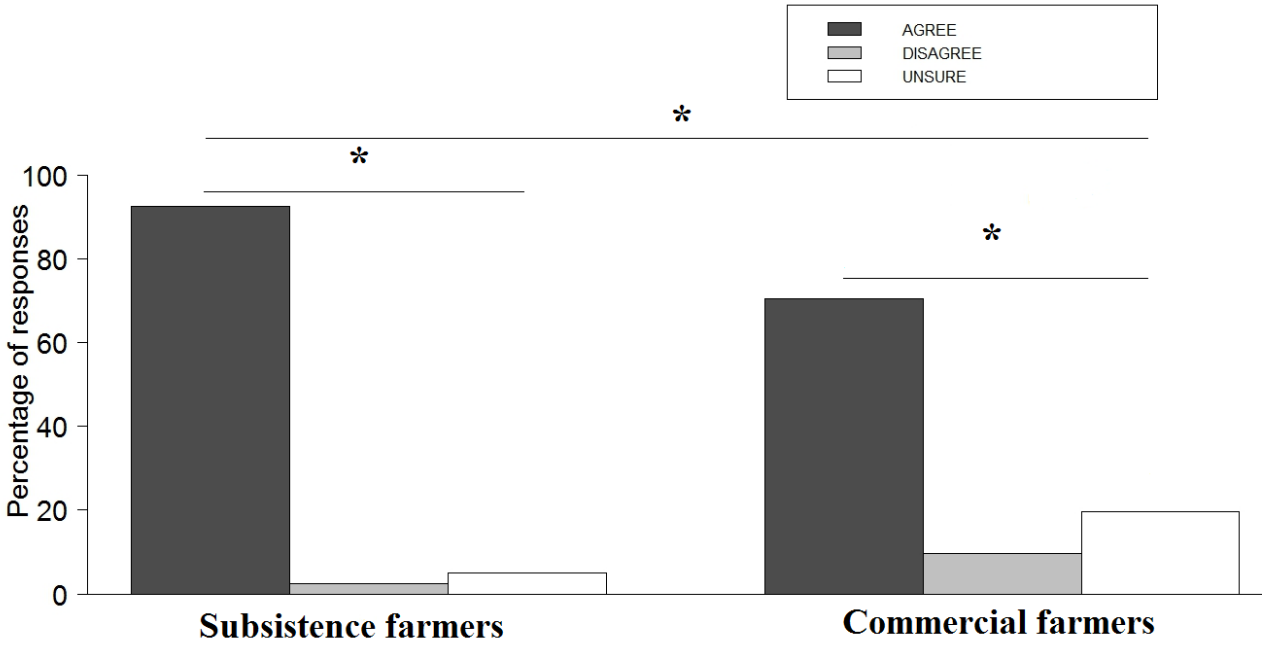


Figure 2. Subsistence and commercial farmer response to the statement, 'Wildlife should be kept only in fenced-off areas'. Bars denote absolute proportion of responses for subsistence and commercial farmers separately. * across or above bars represent two levels of interpretation, i.e. significant differences between farmer type and responses. Statistics are provided in Table 6a-b.

Table 5. Comparison of subsistence and commercial farmer responses for each statement/question to show the dominant response, dominant typology and corresponding outcome (negative, positive or neutral) (dependent factors) associated with each statement. Post-hoc letters represent the *P*−values of the linear mixed model generated in **Supplementary material:** Tables S1 and S2.

Statement/Question	**Proportion of farmers (average per location) and their response with post-hoc letters[abc] representing significant differences between responses**		**Dominant response**	**Dominant typology**	**Outcome**
	Subsistence farmers	**Commercial farmers**			
1. There are good things about wild animals	76% Agreed[a]	85% Agreed[a]	Agree	A – aesthetic and economic value of wildlife	Positive
	19% Disagreed[b]	12% Disagreed[b]			
	7% Unsure[c]	3% Unsure[c]			
2. Wild animals bring tourists, and this is good for our community/farm	88% Agreed[a]	63% Agreed[a]	Agree	A – aesthetic and economic value of wildlife	Positive
	3% Disagreed[b]	20% Disagreed[b]			
	9% Unsure[b]	17% Unsure[b]			
3. I want to learn more about environmental education	91% Agreed[a]	97% Agreed[a]	Agree	E – ecocentric values	Positive
	6% Disagreed[b]	0% Disagreed[b]			
	6% Unsure[b]	3% Unsure[b]			
4.I want to see fewer wild animals in this village	53% Agreed[a]	42% Agreed[a]	Agree	B – damage-causing ability and the negative potential of wild animals	Negative
	31% Disagreed[b]	48% Disagreed[b]			
	16% Unsure[c]	10% Unsure[c]			
5. Problem animals cost me money	65% Agreed[a]	80% Agreed[a]	Agree	B – damage-causing ability and the negative potential of wild animals	Negative
	12% Disagreed[b]	20% Disagreed[b]			
	24% Unsure[b]	0% Unsure[b]			
6. Problem animals are pests and take far more than they need	61% Agreed[a]	97% Agreed[a]	Agree	B – damage-causing ability and the negative potential of wild animals	Negative
	10% Disagreed[b]	3% Disagreed[b]			
	32% Unsure[c]	0% Unsure[c]			

Statement/Question	Proportion of farmers (average per location) and their response with post-hoc letters[abc] representing significant differences between responses		Dominant response	Dominant typology	Outcome
	Subsistence farmers	Commercial farmers			
7. Animals are God's creation, and we must not harm them	86% Agreed[a]	74% Agreed[a]	Agree	C – the moralistic and humanistic interests of respondents	Positive
	5% Disagreed[b]	16% Disagreed[b]			
	9% Unsure[b]	10% Unsure[b]			
8. I want to learn more about non-harmful ways to keep wild animals away	76% Agreed[a]	85% Agreed[a]	Agree	E – ecocentric values	Positive
	19% Disagreed[b]	12% Disagreed[b]			
	7% Unsure[c]	3% Unsure[c]			
9. Wildlife should be kept only in fenced-off areas	93% Agreed[a]	71% Agreed[d]	Agree	B – damage-causing ability and the negative potential of wild animals	Negative
	2% Disagreed[b]	10% Disagreed[e]			
	5% Unsure[c]	0% Unsure[f]			
10. It does not matter if wild animals kill a few of my animals/ destroy some of my crops	13% Agreed[a]	3% Agreed[a]	Disagree	D – the utilitarian personalities of people	Negative
	72% Disagreed[b]	97% Disagreed[b]			
	15% Unsure[a]	0% Unsure[a]			
11. If you remove/kill a problem animal, another one will return	45% Agreed[a]	74% Agreed[a]	Agree	E – ecocentric values	Positive
	27% Disagreed[b]	20% Disagreed[b]			
	29% Unsure[c]	6% Unsure[c]			
12. Killing problem animals is cheaper than protecting my crops/stock in other ways	41% Agreed[a]	13% Agreed[a]	Disagree	E – ecocentric values	Positive
	34% Disagreed[b]	65% Disagreed[b]			
	25% Unsure[a]	34% Unsure[a]			
13. Are there any wild animals that you would like to see on your village/farm?	44% Yes[a]	33% Yes[a]	No	B – damage-causing ability and the negative potential of wild animals	Negative
	54% No[b]	41% No[b]			
	2% No response[c]	26% No response[c]			

Table 6. a) Output of a generalised linear mixed model by maximum likelihood, comparing response of subsistence and commercial farmers (fixed factors) to the statement, 'Wildlife should be kept only in fenced−off areas', and b) Comparison of trichotomous responses to show the dominant response and corresponding outcome.

Generalised linear mixed model fit by maximum likelihood				**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Higher impacted variable**	**Dependent variable**		**df**	**Std. Error**	**Z value**	***P***
Subsistence vs commercial farmer	Subsistence	Percentage of response		15	0.09	-3.13	0.002
b) Statement	**Comparison of responses**	**Dominant response**	**Outcome**	**df**	**Std. Error**	**Z value**	***P***
Wildlife should be kept only in fenced-off areas	Agree vs disagree	Agree	Negative		0.17	-14.12	< 0.001
	Agree vs unsure				0.13	-13.74	< 0.001
	Disagree vs unsure			14	0.20	-3.55	< 0.001

Opinions regarding free-ranging wild animals

Farmer type did not predict opinions in response to the question 'Are there any wild animals that you would like to see on your village/farm?' 'No' responses to the presence of free-ranging wildlife were the most frequent, demonstrating a negative outcome for free-ranging wildlife by all farmers (Fig. 3; Table 7a-b).

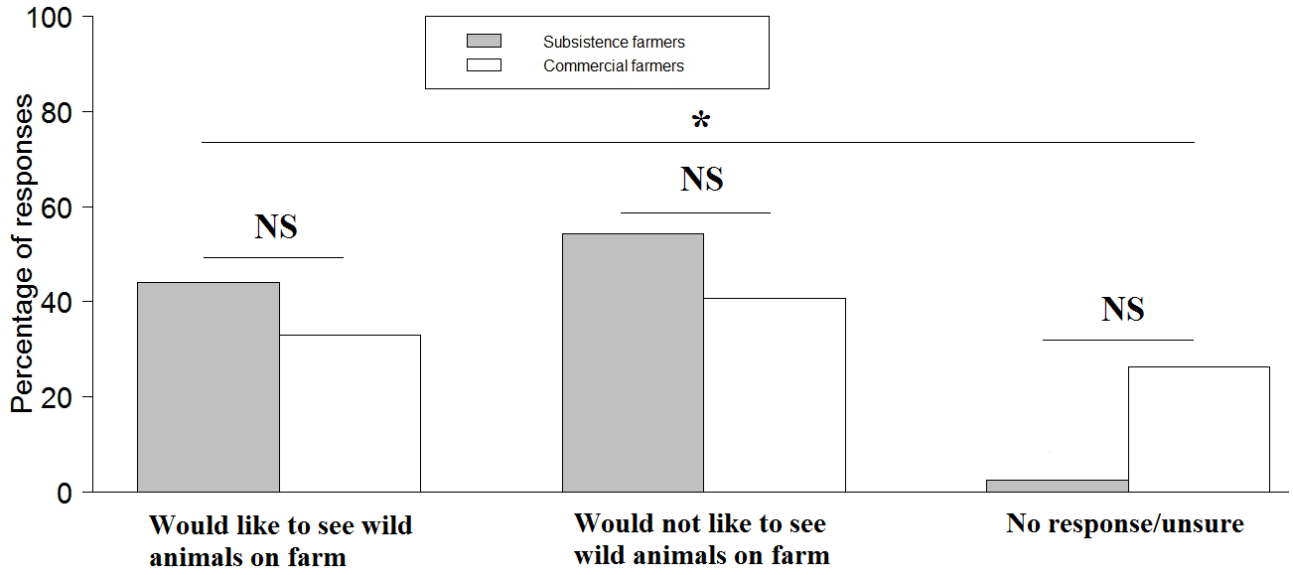


Figure 3. Subsistence and commercial farmer response to the question, 'Are there any wild animals that you would like to see on your village/farm?' Bars denote absolute proportion of responses for subsistence and commercial farmers separately. * across bars represent significant differences between the type of responses. NS denotes no significant differences between subsistence and commercial farmers. Statistics are provided in Table 7a-b.

Table 7. a) Output of a generalised linear mixed model by maximum likelihood, comparing response of subsistence and commercial farmers (fixed factors) to the question, 'Are there any wild animals that you would like to see on your village/farm?', and b) Comparison of trichotomous responses to show the dominant response and corresponding outcome.

Generalised linear mixed model fit by maximum likelihood				**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Higher impacted variable**	**Dependent variable**		**df**	**Std. Error**	**Z value**	***P***
Subsistence vs commercial farmer	No difference	Percentage of responses		15	0.07	0.48	0.630
b) Question	**Comparison of responses**	**Dominant response**	**Outcome**	**df**	**Std. Error**	**Z value**	***P***
Are there any wild animals that you would like to see on your village/farm?	Yes vs No	No	Negative	14	0.08	2.58	0.010
	Yes vs No response				0.12	-8.16	< 0.001
	No vs No response				0.12	10.08	< 0.001

When asked about which animals the respondents would like to see on their farms, only 56 of 110 (51%) subsistence farmers were willing to participate. Of these, 42 of 56 (75%) held positive opinions towards the presence of antelope or zebra *Equus* spp., while one of the 56 respondents (2%) did not want to see any wildlife. The remaining 23% of subsistence farmer participants (13 of 56) wanted to see mega-herbivores, birds or 'the Big Five'. The responses were open-ended with the following common answers: Respondents from Giyani cited "antelope and zebra, all non-dangerous game"; Ndumo respondents mentioned "birds"; Komatipoort stated, "Giraffe *Giraffa camelopardalis* because it is beautiful and they must be free to walk around, elephant *Loxodonta africana* and Big Five." Only four of the 18 commercial farmers interviewed (22%) wanted to answer in this question. All four had positive opinions towards wildlife.

Opinions regarding conservation authorities

Respondents were asked whether they elicited help from conservation authorities with problem animals. In total, 48 of 128 farmers (38%) responded 'yes'. This comprised 35 of 110 subsistence farmers (32%) and 13 of 18 commercial farmers (72%). Farmer type did not predict opinions in response to the question, 'Did you ask conservation authorities for help with the problem animal?' but 'yes' responses were greater than 'no' and 'no response' (Fig. 4; Table 8a-b). This outcome demonstrated a willingness to communicate with PA management.

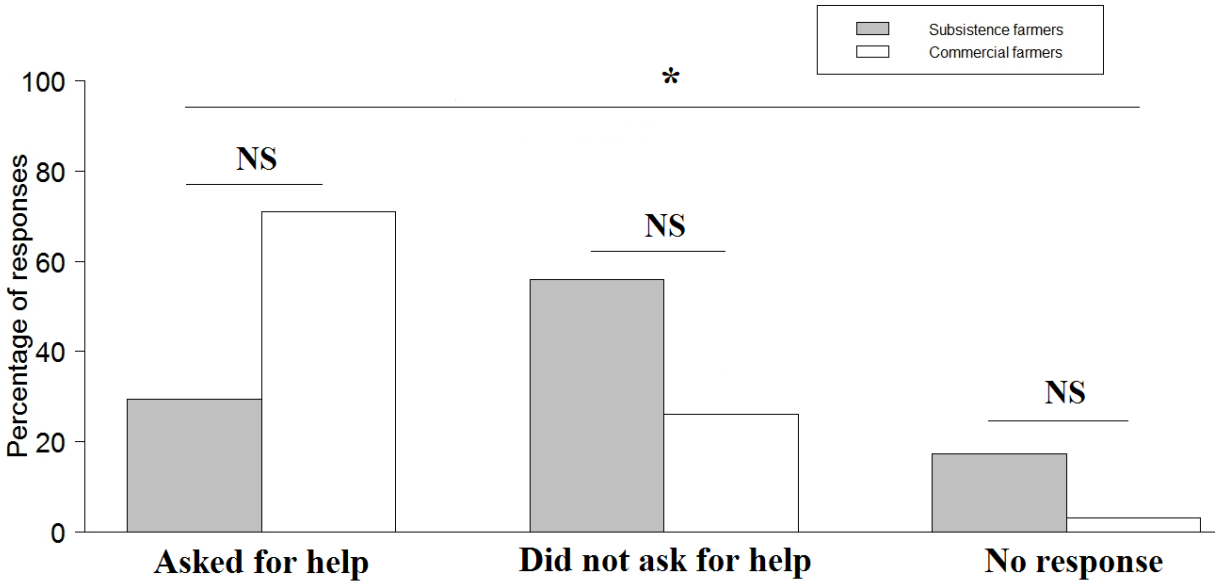


Figure 4. Subsistence and commercial farmer response to the question, 'Did you ask conservation authorities for help with the problem animal?' Bars denote absolute proportion of responses for subsistence and commercial farmers separately. * across bars represent significant differences between the type of responses. NS denotes no significant differences between subsistence and commercial farmers. Statistics are provided in Table 8a-b.

Table 8. a) Output of a generalised linear mixed model by maximum likelihood, comparing response of subsistence and commercial farmers (fixed factors) to the question, 'Did you ask conservation authorities for help with the problem animal?', and b) Comparison of trichotomous responses to show the dominant response and corresponding outcome.

Generalised linear mixed model fit by maximum likelihood				**Coefficient estimates for correlation of fixed effects**			
a) Fixed-effect parameters	**Higher impacted variable**	**Dependent variable**		**df**	**Std. Error**	**Z value**	***P***
Subsistence vs commercial farmer	No difference	Percentage of responses		15	0.08	0.33	0.750
b) Question	**Comparison of responses**	**Dominant response**	**Outcome**	**df**	**Std. Error**	**Z value**	***P***
Did you ask conservation authorities for help with the problem animal?	Yes vs No	Yes	Positive	14	0.09	-2.35	0.019
	Yes vs No response				0.14	-11.37	< 0.001
	No vs No response				0.14	9.75	< 0.001

When asked from whom did the respondent elicit help with the problem animal, the responses were open-ended with four primary answers persisting among respondents, namely 'game parks', 'police', 'village chief' or 'other'. Only 35 of 110 (32%) subsistence farmers wanted to participate in this question. Of these, 22 of 35 (63%) requested help from game parks, while three of 35 respondents (9%) requested help from the village chief. The

remaining 28% of the subsistence farmers (10 of 35) did not want to specify from whom they requested help. Only 14 of 18 commercial farmers interviewed (78%) wanted to participate in this question. Of those commercial farmers that participated, one respondent (7%) requested help from the police, four respondents (29%) requested help from game parks and nine respondents (64%) did not want to specify from whom they elicited assistance.

Respondents were also asked, 'How would you like people working for Parks to help you?' This elicited the following primary responses, 'protection', 'better fencing', 'compensation', 'more frequent communication', 'better/more environmental education', 'can't help' and 'other'. Only 38 of 110 (35%) subsistence farmers wanted to participate in this question. Most subsistence farmers, 12 of 38 respondents (32%), requested help with better fencing; however, after discussions, it emerged that most wanted help with the maintenance of their garden fencing and not park fences. Three subsistence farmers (8%) requested compensation from park authorities for alleged damages incurred due to DCAs, while two (5%) requested park authorities to offer environmental education. Four subsistence farmers (11%) indicated that park authorities 'can't help' with HWC-related issues. The remaining 34% of the subsistence farmers (13 of 38) did not want to specify how they would like park authorities to assist them. All commercial farmers interviewed participated in this question (n = 18). Seven commercial farmers (39%) requested authorities to maintain the fencing of PAs better, while four (22%) requested that park authorities offer environmental education. An additional four respondents (22%) did not want to specify how they would like park authorities to assist them. The remaining three respondents (6%) requested assistance with compensation for alleged DCA-related damages, requested more frequent communication from park authorities (6%) or indicated park authorities 'can't help' with HWC-related issues (6%).

Geographic information system attitude index

The GIS attitude index highlights areas of low (positive attitudes) and high (negative attitudes) conservation concern. Hence, the more negative the attitude index, the greater the potential threat to the persistence of wildlife within that geographic area (Page et al., 2015). Subsistence farmers produced the most negative attitude score (-18 out of a maximum negative score of -25) (Fig. 5a) compared with commercial farmers (-7 out of a maximum negative score of -25) (Fig. 5b).

The attitude index for subsistence farmers ranged from +14 to -18, commercial farmers scored from +5 to -7 (Fig. 5a-b.). Giyani and Ndumo in the Limpopo and KwaZulu-

Natal Provinces generated the most negative subsistence-farmer attitude scores towards wildlife, respectively (Fig. 5a). The attitude index map for subsistence farmers highlights these areas of high concern with the largest dark blue GPS data points (Fig. 5a). Commercial farmers from Giyani produced the most negative attitude scores towards wildlife, and the commercial-farmer attitude index map (Fig. 5b) highlights these areas of high concern with the largest dark orange GPS data points. The most positive attitude scores of subsistence farmers persisted in the Komatipoort and Ndumo areas of the Mpumalanga and KwaZulu-Natal Provinces. The subsistence-farmer attitude index map (Fig. 5a) illustrates the areas of low concern and a high potential for co-existence between subsistence farmers and wildlife with the smallest light blue GPS data points. The most positive attitude scores of commercial farmers occurred in Giyani and Ndumo.

The commercial-farmer attitude index map (Fig. 5b) illustrates the areas of low concern and high potential for commercial farmer-wildlife co-existence with the smallest light orange GPS data points. Notably, very negative and very positive attitude scores overlap in the same geographic areas of Giyani (western border of KNP) and Ndumo for both subsistence and commercial farmers (Fig. 5a-b). Statements used in the generation of the GIS attitude index and their scores are available in **Supplementary material**: Table S3.

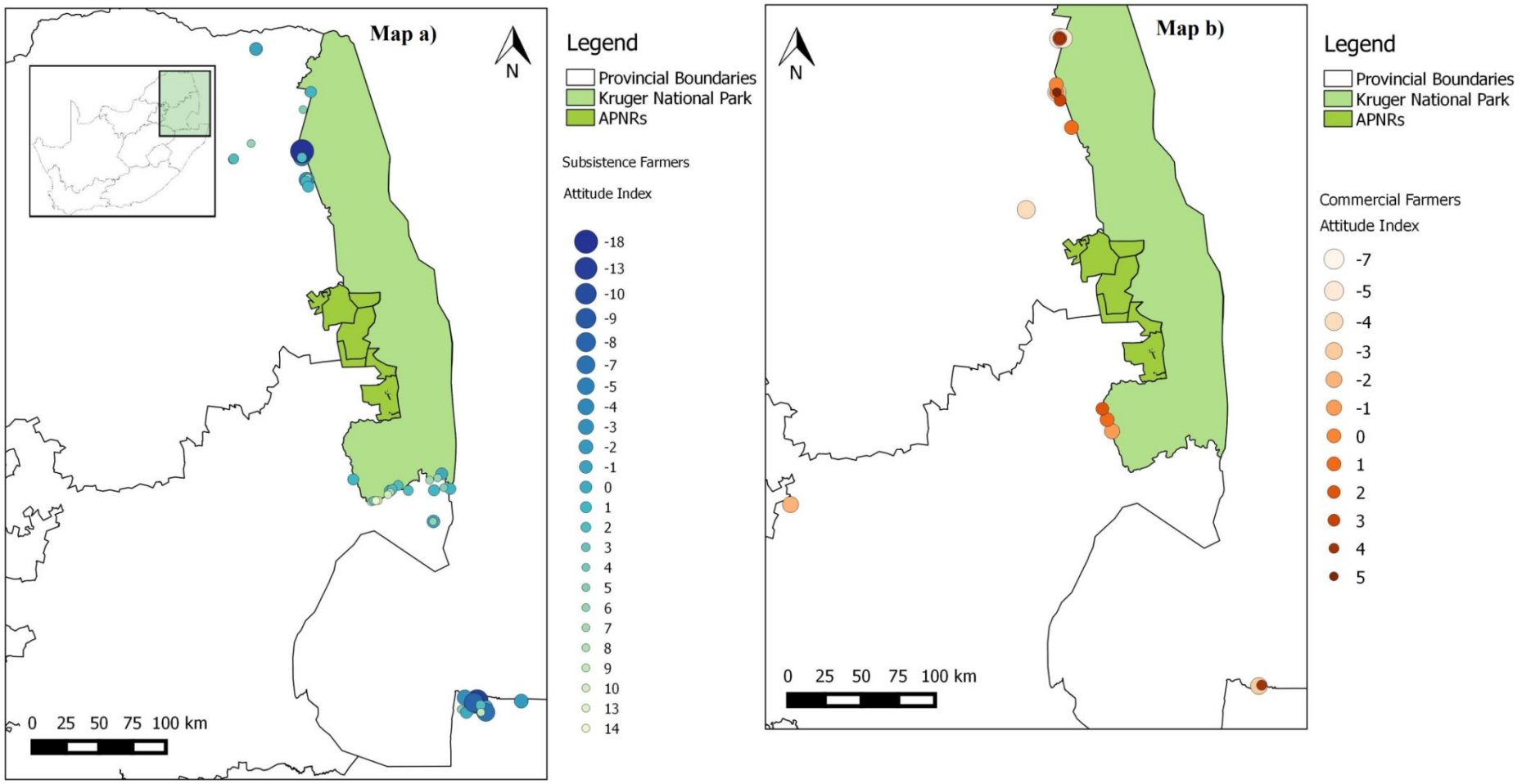


Figure 5. Comparison of geographic information system attitude index scores of a) subsistence farmers and b) commercial farmers. Circles of various sizes are global positioning system data points that represent attitude index scores. Larger circles denote negative attitudes and smaller circles denote positive attitudes. A full index is included in the map legend. A map of South Africa is provided in the inset.

Discussion

This study set out to evaluate the attitudes and opinions of subsistence and commercial farmers towards wildlife and conservation issues. My findings showed that subsistence and commercial farmers hold both negative and positive attitudes towards wildlife. Subsistence farmers more frequently agreed that wildlife should be kept only in fenced-off areas, which was not supported by commercial farmers generally. Overall, Typology B (damage-causing ability and negative potential of wild animals) and Typology E (ecocentric values) determined the attitudes of the majority of subsistence and commercial farmers. Moreover, respondents showed positive attitudes that appealed to the aesthetic and economic value of wildlife (Typology A), the moralistic and humanistic interests of people (Typology C), as well as the utilitarian attributes of people that dictate the use of lethal or non-lethal retaliatory practices in dealing with HWC (Typology D).

Collectively, positive attitudes pertained to environmental education, tourism and willingness to learn about non-harmful wildlife control, with positive outcomes stemming equally from both subsistence and commercial farmers. These results were consistent with those of Lindsey et al., (2005) in which positive rancher attitudes were correlated with the ecotourism value of carnivores. From informal discussions during interviews, the positive attitudes of subsistence and commercial farmers in my study stemmed from the prospect of employment and revenue creation. This could be achieved through ecotourism and the potential to gain information, mentorship and knowledge through environmental education from PA authorities (Lindsey et al., 2005). In addition, subsistence and commercial farmers were open to learning about non-harmful wildlife control and admitted that killing problem animals is not always the best solution in dealing with DCAs.

Typology B was the dominant typology associated with negative attitudes: the damage-causing ability of wildlife and the negative potential of wild animals to depredate farming resources. Generally, respondents produced negative attitudes towards free-ranging wildlife and perceived wildlife as pests or vermin that were an economic threat to their livelihoods. Respondents showed low-tolerance for resource damage (crop and livestock) and wildlife that transgressed the PA boundary, with the more negative attitudes emanating from subsistence farmers towards edge effects (fence transgressions). Similarly, Anthony (2007) showed that negative attitudes appeared to stem from a lack of conservation-management control over wildlife ranging outside PAs, which seemed to be a concern for local people. Anthony (2007) further suggested that local communities in Giyani, Limpopo Province

affected by HWC, fostered mistrust with conservation authorities due to people not receiving compensation for losses after PA authorities pledged that HWC-associated reparations would be forthcoming. Livestock keepers may exploit compensation schemes and falsely claim that livestock and poultry damaged as a result of other causes were depredated, intensifying the economic burden of such schemes (Nyhus et al., 2003). In addition, despite the deep hostility provoked by depredation, local interest in compensation schemes can be poor, especially when such approaches are new or when acts of depredation are infrequent (Anthony, 2007). Moreover, payments for verified depredation do not compensate for the additional costs, such as time expended on shepherding and risks of predation associated with livestock guarding (Macdonald et al., 2010). Therefore, compensation schemes face several drawbacks that make it difficult to abate hostility towards depredators.

Only a third of respondents (38%) indicated that they elicited help with the HWC problem. These findings might undermine HWC mitigation; for example, retaliatory killing of wildlife increased when communication between local communities and park authorities deteriorated (Jackson and Wangchuck, 2001). Madden (2004) suggests that conservation organisations should foster regular communication and trust between PAs and local communities, which might lead to positive effects on the attitudes and behaviour of people in conflict with wildlife. After considering my findings, I suggest subsistence farmers in particular would benefit from more frequent communication with PA authorities, which may influence attitudes and opinions of farmers in South Africa. Many scholars advocate conservation authorities in post-apartheid South Africa to shift their management approach from colonial-based ideologies of biodiversity preservation (Cock and Fig, 2000; DeGeorges and Reilly, 2008) to community-based conservation (Cock and Fig, 2000; DeGeorges and Reilly, 2008; Maddox, 2002) to alleviate racial exclusion of local people from the management of biodiversity and the sustainable use of natural resources.

Interestingly, compensation and fencing were among the issues for which respondents requested help from conservation authorities. Financial values can placate the behaviour and attitudes of people. However, Boonzaier (1996) warned that unrealistic expectations of compensation for wildlife-related depredations in the Richtersveld, South Africa, may result in farmer hostility towards conservation authorities who fail to deliver the anticipated reparations. Moreover, people may expect financial compensation and resent certain species that were not associated with a direct profit (Boonzaier, 1996).

Fence transgression by wildlife is a major concern for both farmers and conservation managers because it threatens farmers' livelihoods and the persistence of both free-ranging

and stray wildlife. The majority of subsistence and commercial farmers were opposed to the presence of perceived dangerous wild animals on their farm. However, the aesthetic regard for wildlife in a minority of respondents was evident, and these perceived wild ungulates as beautiful and were accepting of such species roaming the village or community.

Subsistence farmers generated the most negative attitude score of -18. I established that subsistence farmers were lower-income earners than commercial farmers (Chapter 4). These findings are in line with Infield (1988), who demonstrated that diminished household income negatively influenced attitudes towards wildlife in KwaZulu-Natal Province. It is however noteworthy that a study in the same area documented that the majority of rural subsistence pastoralists were generally positive toward wild dogs in particular, which was attributed to the absence of livestock depredation and the reasonably high levels of formal education amongst questionnaire respondents (Parker et al., 2014). In my study, the range of positive to negative attitudes for commercial farmers (+5 to -7) was much narrower than for subsistence farmers (+14 to -18). Hence, some subsistence farmers indicated a positive attitude to wildlife. Traditional land-use ethics and the values of local people who co-existed with wildlife for many centuries could play a role in shaping positive attitudes of subsistence farmers today (DeGeorges and Reilly, 2008). Notably, the median for both types of farmers seems about the same (neutral or weakly negative), but the range of view for commercial farmers is narrower which could be attributed to a smaller sample size for this population.

According to the attitude index maps, Giyani and Ndumo from the Limpopo and KwaZulu-Natal Provinces were areas of high concern and in which the most negative attitudes prevailed for subsistence households and commercial farmers. Consequently, higher likelihoods of HWC can be expected in these areas. These are impoverished parts of the country, and it is likely that poverty and large households (Chapter 4) are important predictors of hostility towards wildlife. Perhaps conservation outreach initiatives should be focused in these areas for HWC mitigation. Notably, very negative and very positive attitude scores overlapped in the same areas in Giyani and Ndumo for both subsistence and commercial farmers. It would be interesting to investigate whether these varying attitudes of people from the same area depend on an individual's experiences, or cultural and religious beliefs as hypothesised by Kellert (1993).

Conclusions

This investigation offers the first direct comparison of attitudes towards wildlife by concurrently operating subsistence and commercial farmers. My study established that the attitudes and opinions of subsistence and commercial farmers to wildlife are similar. Through negative attitude index scores, I highlighted areas of high conflict risk in which greater likelihoods of HWC could potentially occur. Negative attitudes prevailed for particular variables and typologies, especially the damage-causing ability and negative potential of wild animals to depredate farming resources. Farmers perceived free-ranging and stray wild animals as a threat and a serious economic threat to farmer livelihoods, with both subsistence and commercial farmers displaying low tolerance for resource damage. These attitudes may be motivated by both the perceived nutritional impacts on subsistence households in particular, and economic threats to their livelihoods. Positive attitudes were related to ecocentric values, a willingness to learn about non-harmful wildlife control (both subsistence and commercial farmers), and the prospect of employment through ecotourism revenue (subsistence farmers). Future research should examine the attitudes and opinions of conservation authorities towards local people with regard to the several variables examined in this chapter, such as communication with communities, community-conservation and the deterrent mechanisms implemented to control potential DCAs, to investigate interactions between these two groups.

Examining the cultural beliefs of people was beyond the scope of this study. Yet, cultural and religious beliefs play an important role in influencing people's attitudes towards wildlife worldwide (Dickman, 2010). For example, taboos regarding certain animals may increase tolerance of wildlife and afford protection (Hutton and Leader-Williams, 2003) or promote antagonism towards biodiversity (Maddox, 2002). The Maasai population in Tanzania often perceive spotted hyena *Crocuta crocuta* with hostility even though hyena exert a small impact on livestock. This might be because within Maasai culture, hyenas are associated with gluttony, stupidity and bewitchment (Maddox, 2002). Similarly, Evangelists in Kenya associate carnivores with hostility and were unwilling to employ livestock-husbandry techniques because they trusted God to protect their stock (Hazzah, 2006). Conversely, Buddhists in Nepal are tolerant of snow leopard depredations despite tangible evidence of snow leopard-related damages (Ale, 1998). Buddhists associate these felids with sacredness and thus are prohibited to practise lethal control (Ale, 1998). Examining relationships between wildlife and people with rich cultural diversity in South

Africa will undoubtedly yield interesting results regarding traditional and cultural variables that influence behaviours, attitudes and opinions towards wildlife.

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Supplementary material

Table S1. Output of a generalised linear mixed model by maximum likelihood, comparing the response of subsistence and commercial farmers (fixed factors) for each statement/question.

Statement/Question	Generalised linear mixed model fit by maximum likelihood			Coefficient estimates for correlation of fixed effects			
	Fixed-effect parameters	**Higher impacted variable**	**Dependent variable**	**df**	**Std. Error**	**Z value**	***P***
1. There are good things about wild animals	Subsistence vs commercial farmer	No difference	Percentage of responses	15	0.08	0.65	0.52
2. Wild animals bring tourists, and this is good for our community/farm		No difference		15	0.08	0.00	0.99
3. I want to learn more about environmental education		No difference		15	0.08	-0.33	0.75
4. I want to see fewer wild animals in this village		No difference		15	0.08	0.00	0.99
5. Problem animals cost me money		No difference		15	0.08	0.08	0.94
6. Problem animals are pests and take far more than they need		No difference		15	0.08	0.33	0.75
7. Animals are God's creation, and we must not harm them		No difference		15	0.08	0.33	0.99
8. I want to learn more about non-harmful ways to keep wild animals away		No difference		15	0.08	0.00	0.99
9. Wildlife should be kept only in fenced-off areas		**Subsistence**		15	0.09	-3.13	0.002
10. It does not matter if wild animals kill a few of my animals / destroy some of my crops		No difference		15	0.08	0.00	0.99
11. If you remove/kill a problem animal, another one will return		No difference		15	0.08	0.04	0.97
12. Killing problem animals is cheaper than protecting my crops/stock in other ways		No difference		15	0.01	0.00	0.99
13. Are there any wild animals that you would like to see on your village/farm?		No difference		15	0.07	0.48	0.63

Table S2. Output of a generalised linear mixed model by maximum likelihood, comparing trichotomous responses to show the dominant response (dependent factors) for each statement.

Statement/Question	Comparison of responses	Dominant response	Coefficient estimates for correlation of fixed effects			
			df	Std. Error	Z value	*P*
1. There are good things about wild animals	Agree vs disagree	Agree	14	0.11	-14.58	< 0.001
	Agree vs unsure			0.16	-15.16	< 0.001
	Disagree vs unsure			0.18	4.3	< 0.001
2. Wild animals bring in tourists, and this is good for our farm/community	Agree vs disagree	Agree	14	0.13	-14.6	< 0.001
	Agree vs unsure			0.12	-14.44	< 0.001
	Disagree vs unsure			0.17	-0.58	0.56
3. I want to learn more about environmental education	Agree vs disagree	Agree	14	0.25	-14.22	< 0.001
	Agree vs unsure			0.19	-15.5	< 0.001
	Disagree vs unsure			0.31	-1.62	0.11
4. I want to see fewer wild animals in this village	Agree vs disagree	Agree	14	0.09	-2.01	0.040
	Agree vs unsure			0.12	-10.11	< 0.001
	Disagree vs unsure			0.13	8.55	< 0.001
5. Problem animals cost me money	Agree vs disagree	Agree	14	0.11	-13.46	< 0.001
	Agree vs unsure			0.13	-14.18	< 0.001
	Disagree vs unsure			0.16	1.86	0.06
6. Problem animals are pests and take far more than they need	Agree vs disagree	Agree	14	0.17	-14.98	< 0.001
	Agree vs unsure			0.11	-14.32	< 0.001
	Disagree vs unsure			0.19	-4.77	< 0.001
7. Animals are God's creation and we must not harm them	Agree vs disagree	Agree	14	0.13	-15.13	< 0.001
	Agree vs unsure			0.14	-15.22	< 0.001
	Disagree vs unsure			0.18	0.91	0.36

Statement/Question	Comparison of responses	Dominant response	Coefficient estimates for correlation of fixed effects			
8. I want to learn more about non-harmful ways to keep wild animals away	Agree vs disagree	Agree	14	0.12	-14.89	< 0.001
	Agree vs unsure			0.15	-15.16	< 0.001
	Disagree vs unsure			0.18	2.41	0.016
9. Wildlife should be kept only in fenced-off areas	Agree vs disagree	Agree	14	0.17	-14.12	< 0.001
	Agree vs unsure			0.13	-13.74	< 0.001
	Disagree vs unsure			0.2	-3.55	< 0.001
10. It does not matter if wild animals kill a few of my animals / destroy some of my crops	Agree vs disagree	Disagree	14	0.15	15.61	< 0.001
	Agree vs unsure			0.21	-0.41	0.68
	Disagree vs unsure			0.16	15.56	< 0.001
11. If you remove/kill a problem animal, another one will return	Agree vs disagree	Agree	14	0.1	-9.43	< 0.001
	Agree vs unsure			0.11	-11.02	< 0.001
	Disagree vs unsure			0.13	2.17	0.030
12. Killing problem animals is cheaper than protecting my crops/stock in other ways	Agree vs disagree	Disagree	14	0.1	6.35	< 0.001
	Agree vs unsure			0.12	-1.04	0.3
	Disagree vs unsure			0.1	7.27	< 0.001
13. Did you ask conservation authorities for help with the problem animal?	Yes vs No	Yes	14	0.09	-2.35	0.019
	Yes vs No response			0.14	-11.37	< 0.001
	No vs No response			0.14	9.75	< 0.001

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5461 **Table S3.** Raw data for the calculation of attitude index scores for attitudes of subsistence and commercial farmers towards wildlife.

There are good things about wild animals	Wild animals bring tourists, and this is good for our community/farm	I want to learn more about environmental education	I want to see fewer wild animals in this village	Problem animals cost me money	Problem animals are pests	Animals are God's creation, and we must not harm them	I want to learn more about non-harmful ways to keep wild animals away	Wildlife should be kept only in fenced-off areas	It does not matter if wild animals kill a few of my animals / destroy some of my crops	If you remove/kill a problem animal, another one will return	Killing problem animals is cheaper than protecting my crops/stock in other ways	Are there any wild animals that you would like to see on your village/farm?
+2 SA; +1 A; 0 U; -1 D; -2 SD	+2 SA; +1 A; 0 U; -1 D; -2 SD	+2 SA; +1 A; 0 U; -1 D; -2 SD	-2 SA; -1 A; 0 U; 1 D; +2 SD	-2 SA; -1 A; 0 U; 1 D; +2 SD	-2 SA; -1 A; 0 U; 1 D; +2 SD	+2 SA; +1 A; 0 U; -1 D; -2 SD	+2 SA; +1 A; 0 U; -1 D; -2 SD	-2 SA; -1 A; 0 U; 1 D; +2 SD	+2 SA; +1 A; 0 U; -1 D; -2 SD	+2 SA; +1 A; 0 U; -1 D; -2 SD	-2 SA; -1 A; 0 U; 1 D; +2 SD	Positive 1; neg -1; neutral 0
+2 Strongly agree	+2 Strongly agree	+2 Strongly agree	+2 Strongly disagree	+2 Strongly disagree	+2 Strongly disagree	+2 Strongly agree	+2 Strongly agree	+2 Strongly disagree	+2 Strongly agree	+2 Strongly agree	+2 Strongly disagree	+1 Yes= Positive
+1 Agree	+1 Agree	+1 Agree	+1 Disagree	+1 Disagree	+1 Disagree	+1 Agree	+1 Agree	+1 Disagree	+1 Agree	+1 Agree	+1 Disagree	0 I don't know = Neutral
0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure	-1 No= Negative
-1 Disagree	-1 Disagree	-1 Disagree	-1 Agree	-1 Agree	-1 Agree	-1 Disagree	-1 Disagree	-1 Agree	-1 Disagree	-1 Disagree	-1 Agree	
-2 Strongly disagree	-2 Strongly disagree	-2 Strongly disagree	-2 Strongly agree	-2 Strongly agree	-2 Strongly agree	-2 Strongly disagree	-2 Strongly disagree	-2 Strongly agree	-2 Strongly disagree	-2 Strongly disagree	-2 Strongly agree	

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CHAPTER SEVEN

Conservation practitioner attitudes, opinions and interactions with wildlife and local human communities in north-eastern South Africa

Abstract

Recently, scholars have considered the idea of transition from ecocentric attitudes (concern for ecosystems) and protectionist beliefs (biodiversity can only survive in isolation of anthropogenic disturbance) of protected area management to community co-management of wildlife. The move away from conventional protectionist views depends on the behaviour and attitudes of people working in conservation. I investigated the attitudes, as well as the opinions and interactions, of conservation practitioners towards wildlife and local human communities contiguous with protected areas in the north-eastern provinces of South Africa. Using semi-structured questionnaire interviews and a geographic information system attitude index (spatial distribution of positive and negative attitudes), I specifically 1) compared the attitudes and opinions of conservation practitioners (n=49) towards wildlife and local human communities; 2) classified conservation practitioner responses into discrete typologies ; and 3) investigated whether community-engagement and environmental-education programmes and protected area-trans-boundary monitoring programmes for each province were being implemented. Generally, mixed responses towards wildlife and local human communities prevailed, with no significant differences in attitudes and opinions among practitioners located in each province. Positive responses towards wildlife were associated with the ecocentric, aesthetic and economic values of wildlife. Positive responses towards local human communities related to interests that were oriented to community conservation. It is noteworthy that negative responses towards local human communities pertained to a disinterest and indifference towards the socio-economic needs of local human communities, in addition to protectionist beliefs. Furthermore, conservation practitioners demonstrated predictably negative opinions towards poaching, showing low tolerance for factors that threaten wildlife persistence. I concluded that conservation practitioners harboured mixed attitudes and opinions towards wildlife and local human communities. While positive attitudes have the potential to create collaborations between conservation practitioners and

local human communities, the reasons for the negative and mixed responses require further research to understand the causal reasons for such responses.

Keywords: attitude index, community-conservation, conservation practitioners, ecocentric, poachers, protectionist

Introduction

Confronted by several human-induced impediments, such as the rapidly increasing human population (Thornton et al., 2011) and corresponding extensification of agricultural and livestock production activities that encroach onto indigenous habitats, wild animal populations are unlikely to survive without the establishment and management of designated protected areas (PAs) (Bruner et al., 2001). Yet agriculture that often impinges onto PAs, is essential to achieving and sustaining food security and is the mainstay for economic growth, especially in developing countries (Thornton et al., 2011). Governments and PA managers are, therefore, faced with a dilemma: how to manage biodiversity and people that live on PA boundaries where the resource needs of both wildlife and local human communities overlap, often resulting in human-wildlife conflict (HWC)?

Throughout the African continent, thousands of indigenous people were displaced in order to establish PAs (Carruthers, 1995; Cock and Fig, 2000; DeGeorges and Reilly, 2008). Indigenous people were subsequently compressed into overcrowded settlements on the edge of PAs (Carruthers, 1995; DeGeorges and Reilly, 2008). This scenario amplified interactions and potential incidences of HWC, raising tensions between PA management and local human communities (Anthony, 2007). In addition, the human settlements contiguous with PAs characteristically involve the poor and most vulnerable people in terms of food security and socio-economic circumstances regarding education, health and infrastructure (Anthony, 2007; DeGeorges and Reilly, 2008).

Since European colonisation of Africa, conventional ideologies of conservation were based on preservation and posterity, alienating human communities from the management of natural resources (Carruthers, 1995: DeGeorges and Reilly, 2009). Communities were disenfranchised as crucial stakeholders (Khan, 1994) and hence, abdicated their role in the conservation of biodiversity (Anthony, 2007). Consequently, the management of PAs to provide security and control over wildlife movement has become expensive, with wildlife

being at risk of farmer or community retaliation following HWC (Woodroffe and Frank, 2005), poaching and in some cases, subsistence hunting (DeGeorges and Reilly, 2008) that could lead to wildlife population declines. Protected-area managers also need to contend with compensation demands by communities who suffer wildlife depredation (Anthony, 2007). These issues are fundamental drivers of HWC.

In recent decades there has been discussion of the ideas pertaining to the transition from ecocentric attitudes and protectionist views of PA management to community co-management of wildlife or community-based-natural-resource management (CBNRM; (Child, 1995). This is based on the principle that communities will only seek to manage natural resources when they perceive that the benefits of doing so surpass the costs (Murphree, 1991). Community-based-natural-resource management also bear advantages for PAs since local human communities act as custodians of biodiversity through the education of communities to acquire knowledge concerning modern wildlife conservation approaches (Zhang and Wang, 2003). In addition, community-based conservation is expected to encourage local community-stakeholder participation in the park or PA by providing employment with park management and extending environmental education and community-engagement initiatives to neighbouring communities (Murphree, 1991). Through CBNRM, local communities work to protect wildlife outside PAs and earn benefits from ecotourism and safari/trophy hunting revenue (Child, 1995). For example, in Zimbabwe, CBNRM enabled landowners to convert their farms from unprofitable pastoralism to wildlife conservation and tourism attractions, allowing natural habitats and indigenous wildlife populations to recover; this was achieved through profits from increased employment opportunities and tourist enterprises such as cultural village tours and handcraft sales (Child, 1995).

A paradigm shift in conservation policy implies new outlooks and roles for PA management and local people (Pretty, 1994). It warrants a greater emphasis on community conservation in which conservation practitioners become progressively sensitive to the plight of local people (Pretty, 1994). Some scholars advocate that community engagement should be cultivated through the adoption and use of participatory methods such as environmental-education programmes (Chambers, 1992; Pretty, 1994). The challenges to reverse traditional protectionist views will not be easy to overcome and depend on the behaviour and attitudes of people working in conservation (Pretty, 1994; Stiefel and Wolfe, 1994).

While considerable research has been published on the attitudes and opinions of landowners and farmers towards wildlife (Marker et al., 2003; Schumann et al., 2008; Thorn et al., 2012), limited research is available on how people who manage wildlife and PAs (conservation practitioners) perceive and interact with local communities and farmers (Dr Robert Hitchcock, Pers. Comm. University of New Mexico, Albuquerque). In addition, such interactions between conservation practitioners and local people and farmers are suggested to be important drivers of HWC. For example, retaliatory killing of carnivores increased when communication between local communities and park authorities deteriorated (Jackson and Wangchuck, 2001). Hence, the assessment of the attitudes, as well as the opinions and interactions, of conservation practitioners towards wildlife and local human communities contiguous with protected areas is fundamental to the assessment of HWC mitigation. Human-wildlife conflict issues are suggested to be particularly intense in developing countries (Chapter 2) where a conundrum to mitigate poverty and food insecurity exist alongside conserving biodiversity (DeGeorges and Reilly, 2008; Gilbert and Dodds, 2001; Woodroffe et al., 2005). South Africa, in particular, is beset by a prominent political and socio-economic history in which indigenous people were displaced in favour of establishing PAs (Carruthers, 1995), and this has shaped the conservation policy that exists today (Carruthers, 1995; Cock and Fig, 2000; DeGeorges and Reilly, 2009). In addition, many PAs are being impinged by resident local communities contiguous with PAs reducing the effective size of such PAs and intensifying HWC. Protected-area management is, therefore, an important determinant of how HWC in South Africa is currently managed (DeGeorges and Reilly, 2009) and ultimately contributed to how conservation practitioners perceive, communicate and interact with farmers and local communities. In addition, the deterrent mechanisms implemented to control potential damage-causing animals (DCAs) should be investigated.

The aim of my study was to investigate the attitudes, as well as the opinions and interactions, of conservation practitioners towards wildlife and local human communities contiguous with PAs in the north-eastern provinces of South Africa. Using semi-structured questionnaire interviews and a geographic information system (GIS) attitude index (a method to visualise the spatial distribution of positive and negative attitudes), I 1) compared the attitudes and opinions of conservation practitioners towards wildlife and local human communities; 2) classified conservation practitioner responses into discrete typologies; and 3) investigated whether community engagement and environmental-education programmes and

protected area-trans-boundary monitoring programmes for each province were being implemented by conservation organisations.

I defined attitude as the manner, disposition, feeling or position of conservation practitioners towards local human communities and wild animals, and an opinion (positive, negative or neutral) as a belief towards local human communities and wild animals. In addition, I characterise perception as a conservation practitioner's view and understanding of poaching (the illegal hunting or killing of wild animals, usually concomitant with PA land-use privileges; DeGeorges and Reilly, 2009). I asked, whether conservation practitioners have negative interactions and hold negative attitudes and opinions towards local human communities. This is under the assumption that local communities threaten the persistence of wildlife through a variety of processes, such as retaliatory or deliberate persecution of stray wildlife (Chapter 5), uncontrolled harvesting of biological resources from the park and poaching. I considered the attitudes of conservation practitioners to local human communities in general and not farmers specifically, because local people are affected by problem animals whether they farm or not (human safety).

Materials and methods

Data for this chapter were extracted from survey responses to the questionnaire used in Chapter 3 (Appendix II), and a comprehensive description of methodology concerning data collection, sampling procedures, interview methods, general statistical analysis and GIS methodology is provided in Chapter 3. This study was conducted around PAs and game and nature reserves in north-eastern South Africa (Fig. 1) within the provinces of KwaZulu-Natal, Limpopo and Mpumalanga.

In total, 49 conservation practitioners who were employed within KwaZulu-Natal, Mpumalanga or Limpopo provinces participated in the study. Each province is home to several national parks, provincial nature reserves (managed by provincial departments of Economic Development and Tourism) and local authority nature reserves (managed by municipalities; Driver et al., 2012). Each of these conservation bodies enforce distinct land-management objectives, ranging from strict protection of biological diversity (natural and cultural resources) to limitation of agricultural land use without intensification in order to minimise the impacts on threatened fauna and flora (Driver et al., 2012). The respondents

invited to participate in this study, referred to as conservation practitioners, each worked within one of these conservation bodies.

Assessing attitudes towards wildlife and local human communities

The attitude and perception segment was developed in consultation with Dr Michelle Thorn, a researcher from the Endangered Wildlife Trust who previously piloted a questionnaire survey investigating farmer-carnivore conflict in the Waterberg (Thorn, 2012). Together we modified her original questions regarding the assessment of respondent attitudes to suite the aims and objectives of my study. Notably, factors affecting conservation-practitioner attitudes and opinions towards wildlife and local human communities are complex, and some variables are more difficult to quantify and investigate than others (Kellert, 1993). Attitudes often vary significantly depending on an individual's experiences, principles and cultural and religious tenets (Hunter, 2000; Kellert, 1993). The questionnaire made provision to evaluate several typologies (Kellert, 1993) (Tables 1–2) by allowing for trichotomous responses (viz., agree, disagree and unsure, or yes, no and unsure/no response) (Lindsey et al., 2005; White et al., 2005).

In addition to the questionnaire, I used an open-ended question concerning the opinions of the conservation practitioners regarding CBNRM, the responses for which I presented as illustrated quotes of the most common explanations. Respondents were requested to give their opinion on a number of statements (Table 2) by selecting the option that suited them best (agree, disagree or unsure) as outlined in Chapter 6. Consequently, an association with the dominant typology was distinguished for each statement. These statements and typologies enabled me to evaluate the attitudes, as well as the opinions and perceptions, of conservation practitioners towards wildlife and local human communities and to construct a GIS attitude index (discussed in Chapter 6).

Table 1. Typologies developed to evaluate attitudes, opinions and perceptions of conservation practitioners using guidelines proposed by Kellert (1993).

Typology	Description
A	Concern for the ecosystem (i.e. ecocentric) and the relationships between wildlife and natural habitats
B	Concern for the aesthetic and economic value of wildlife
C	Local people and community-conservation oriented interests
D	Disinterest and indifference towards the socio-economic needs of local human communities
E	Protectionist beliefs that biodiversity can only survive in isolation of anthropogenic disturbance

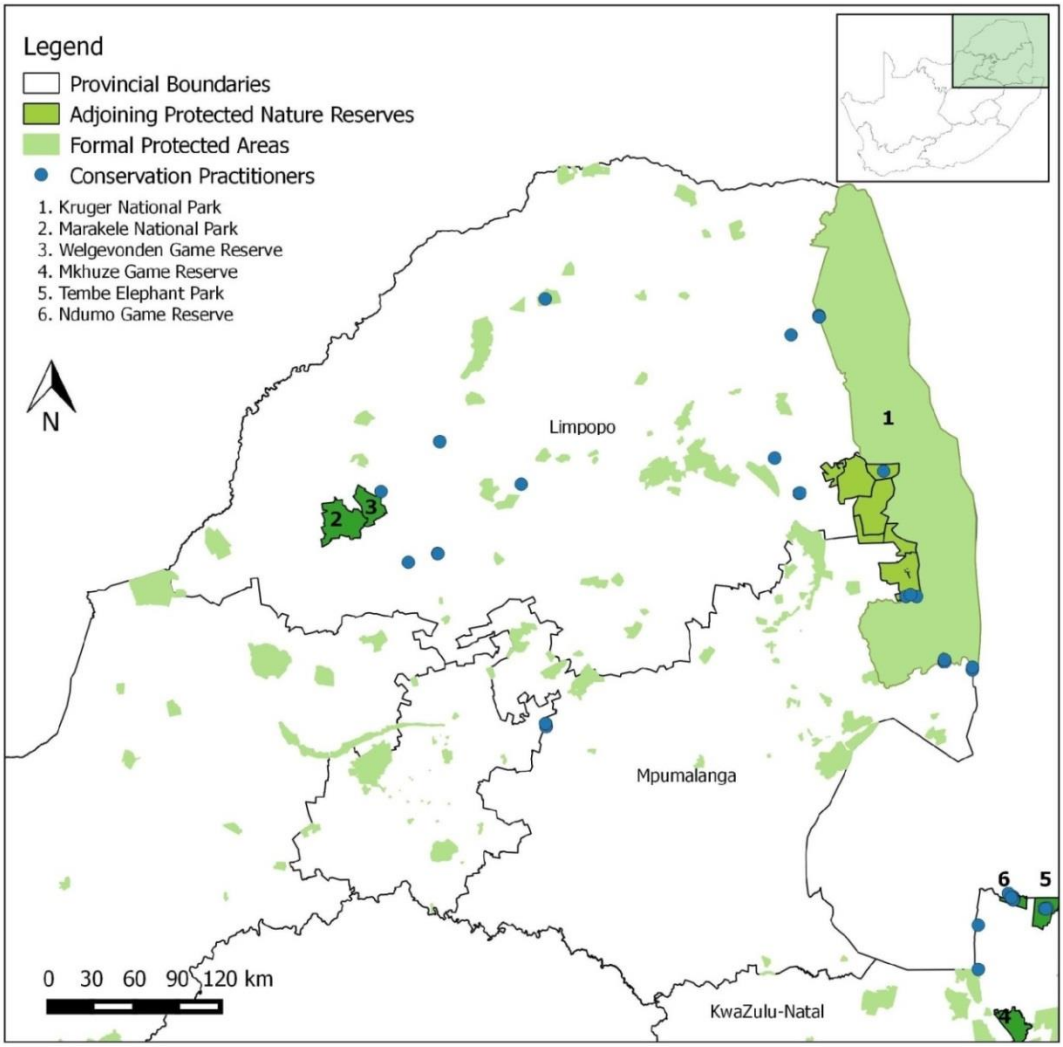


Figure 1. Distribution of conservation practitioners surveyed in the north-eastern South Africa. Blue circles are global positioning system data points that indicate the location of the conservation practitioners that participated in the study. Numbers indicate key protected areas. A map of South Africa is provided in the inset.

Table 2. Statements used in the assessments of the attitudes, opinions and perceptions and the different typologies associated with each attitude.

Statements/Questions	**Typology**
1. Wildlife plays a very important part in our ecosystem	A
2. Wildlife attracts ecotourism	B
3. Agriculture wastes natural habitats	C or E
4. Poverty is not my problem	C or D
5. Poachers are criminals (**perception**)	C or D
6. Rural communities should benefit from tourism revenue	C
7. Educating communities will benefit the reserve	C or E
8. Rural communities can make use of natural resources from/on the reserve	C or E

Geographic information system attitude index

The GIS attitude index scores were calculated using the same procedure as outlined in Chapter 6 but were determined separately for attitudes towards wildlife and local human communities. While the GLMM examined distinctions between attitudes of conservation practitioners per province and their responses, the GIS attitude index provides a geographic distribution of attitudes. For each of the respondents, the value for each index was calculated per interview as the sum of the scores of all questions to evaluate attitudes towards wildlife (Statements 1 to 3) and attitudes towards local human communities (Statements 4 to 8). Index scores were calculated by allocating values of between +2 and -2 to the questions according to a strongly positive (+2), positive (+1), neutral (0), negative (-1) or strongly negative (-2) response towards wildlife or people. For example, for the statement, 'Wildlife attracts ecotourism', a score of +2 was given if the respondent strongly agreed (indicating strongly positive attitudes), +1 if the respondent agreed, 0 if the respondent was unsure or gave no response, -1 if the respondent disagreed and -2 if the respondent strongly disagreed (indicating strongly negative attitudes). The maximum value that could be achieved for attitudes towards wildlife was +6 (a maximum of +2 for three statements), which indicated very positive attitudes for all questions, while −6 was the maximum negative score and indicated a respondent who had very negative attitudes. For the attitudes towards local human communities, the maximum score that could be achieved was +10 (a maximum of +2 for five statements), which indicated very positive attitudes, while −10 was the maximum negative score and indicated a respondent who had very negative attitudes. The attitudes for each respondent were subsequently displayed as maps for attitude indexes (separately for wildlife and local human communities) using Quantum GIS (QGis) 2.8.1 (see Chapter 3: GIS analysis). Although Page et al., (2015) proposed that the higher the negative score for the attitude index, the greater the potential for PAs to alienate communities from PA management, and possibly manifest into threats targeted at wildlife, within that area, I maintain that positive attitudes might provide the basis for future collaboration with local human communities, while negative attitudes might not.

With reference to Statement 6, 'Poachers are criminals', I believe that not many conservation practitioners would perceive uncontrolled harvesting of wild animals as a positive goal of conservation and would hence view poaching as a negative entity. Since the late 1990s, environmentalists have classified poaching as an environmental crime established to regulate the use of biological resources, which includes the unlawful harvesting of wildlife both within and outside PAs (Muth and Bowe, 1998). Therefore, in response to Statement 6,

a strongly agree response incurred a −2 score towards local human communities, while a strongly disagree response received a +2 score towards local human communities. With reference to Statement 8, 'Rural communities can make use of natural resources from/on the reserve', a strongly agree response received a +2 score towards local human communities, indicating goals for conservation-community initiatives and sustainable resource use. A full account of the scoring is available in **Supplementary material:** Tables S9–10.

Data and geographic information system analysis

This study provided both descriptive and quantitative analyses to investigate a variety of variables that were likely to influence the PA management of DCAs and to understand whether or not any of these variables influenced the attitudes of conservation practitioners towards local human communities. Further details concerning statistical analyses and GIS methodology analyses are provided in Chapter 3. Hot spots of low (positive attitudes) and high (negative attitudes) conservation concerns in a GIS attitude index of conservation practitioners towards wildlife and local human communities were generated.

Assessing attitudes, opinions and perceptions of conservation practitioners

To evaluate the outcome of responses (negative, positive or neutral) and the dominant typology associated with each statement, I individually analysed the responses for each statement in Table 2. The result of each statement addressed two sub-questions. 1) Do the responses of conservation practitioners between provinces differ from one another? 2) Which response is dominant for each question? For example, are the numbers of agree responses significantly more than disagree responses, for each question? Depending on the statement and the dominant responses of the conservation practitioners, I evaluated whether the outcome was negative, positive or neutral towards local people and assigned a typology associated with either potential for hostility or coexistence with people. I also assessed whether their attitudes towards wildlife outweighed values towards local people in order to establish whether a predominantly protectionist ideology or community-conservation oriented interests persisted among conservation practitioners.

To compensate for unbalanced sampling of the number of conservation practitioners per province, I examined the number of agree (strongly agree and agree responses were pooled and regarded as agree), disagree (strongly disagree and disagree responses were pooled and regarded as disagree) and unsure responses over the total number of conservation practitioners sampled to produce a percentage of responses for conservation practitioners per

province. The percentages of agree, disagree and unsure responses (dependent factors) produced by conservation practitioners per province (fixed-effect parameters) were analysed using a generalised linear mixed model (GLMM) with a Poisson error structure for count data, in which models were validated by maximum likelihood for each question.

Examining the prevalence of trans-boundary monitoring programmes

Trans-boundary monitoring refers to the monitoring of the perimeter fences or boundaries of protected conservation areas and their surroundings to prevent wild animals from transgressing PA boundaries, and to reduce illegal anthropogenic activities, such as poaching. Using a GLMM, I compared the percentage of respondents who practised trans-boundary monitoring at their affiliated conservation organisation for each province. I also considered the type of response that was dominant (yes or no to the prevalence of the programme). Yes, for example, would indicate that preventing wildlife transgressions is a priority for the park and considers the safety of local human communities (positive). This analysis would therefore determine a positive, negative or neutral outcome towards local human communities and to identify the dominant typology associated with each response.

Assessing the prevalence of environmental-education and community-engagement programmes

Environmental education programmes refer to the teaching of local human communities living contiguous to protected conservation areas about the importance and functioning of ecosystems and how to manage their behaviour to live sustainably, thus enhancing environmental awareness. Community engagement programmes refer to meetings between conservation authorities and local human communities living near PA boundaries in order for all parties to gain knowledge of the natural environment and the hardships faced by the community, to bring awareness to the associated challenges and problems and to engage in solutions to such problems.

I compared the percentage of respondents who implemented environmental-education and community-engagement programmes for each province using a GLMM, in a linear predictor, via maximum likelihood. I also considered the type of response that was dominant (yes or no to the prevalence of the programme) to determine a positive, negative or neutral outcome towards local human communities and to identify the dominant typology associated with each response.

Results

Characteristics of respondents

Language

The dominant languages of the conservation practitioners from Limpopo Province were English (n = 5, 29.4%) and Tsonga (n = 5, 29.4%), while the other respondents were Afrikaans speaking (n = 3, 17.6%). The remaining respondents selected either Ndebele, Sotho, Other or Zulu (n = 1 respondent per language, 5.9% per respondent). A tabulated summary regarding respondent demographics is available in **Supplementary material:** (Tables S1–4). The dominant languages of the conservation practitioners from Mpumalanga Province were English speaking (n = 5, 38.5%), while the other respondents selected Sotho and other (n = 2 per language, 15.4% per language). The remaining respondents were Afrikaans, Ndebele, Venda and Zulu speaking (n = 1 respondent per language, 7.7% per respondent). The majority of the conservation practitioners from KwaZulu-Natal Province were Zulu speaking (n = 11, 57.9%), while the other respondents selected Afrikaans (n = 4, 21%), English (n = 3, 15.7%) or other (n = 1, 5.3%).

Ethnicity

The dominant ethnicity of the conservation practitioners from Limpopo Province was white (n = 7, 41%), followed by other (n = 6, 35.3%) and then Sotho (n = 2, 11.8%), while the remaining respondents selected Ndebele or Zulu (n = 1 respondent per language, 5.9% per respondent). The dominant ethnicity of the conservation practitioners from Mpumalanga Province was white (n = 5, 38.5%), followed by other (n = 2, 15.4%). The remaining respondents selected Ndebele, Sepedi, Sotho, Venda, Zulu or no response (n = 1 respondent per language, 7.7% per respondent). The majority of the conservation practitioners from KwaZulu-Natal Province selected Zulu as their ethnicity (n = 11, 57.9%), while the other respondents selected white (n = 6, 31.6%) and other (n = 2, 10.5%).

Religion

The dominant religion of the conservation practitioners from Limpopo Province was Christian (n = 15, 88%), followed by Zionist (n = 1, 5.9%) no religion (n = 1, 5.9%). The dominant religion of the conservation practitioners from Mpumalanga Province was Christian (n = 4, 30.7%), followed by no religion (n = 3, 23%), Zionist (n = 2, 15.4%) and Catholic (n = 2, 15.4%). The remaining respondents were Lutheran (n = 1, 7.7%) or other (n = 1, 7.7%).

The majority of the conservation practitioners from KwaZulu-Natal Province were Christian (n = 11, 57.9%), followed by Catholic (n = 3, 15.7%) and Zionist (n = 3, 15.7%), while the remaining respondents were Pentecostal (n = 1, 5.3%) and other (n = 1, 5.3%).

At a glance, comparisons between farmers (subsistence and commercial) and conservation practitioners for language and ethnicity demographics showed no similarities. Subsistence farmers and conservation practitioners showed similar religious beliefs throughout the study sites. Further quantitative analysis with equal sampling of all groups of people is required to elucidate these findings.

Formal qualification in conservation

All conservation practitioners from Limpopo Province mentioned that they held formal qualifications in Conservation or a related field (n = 17, 100%), while 69% (9 respondents) from Mpumalanga Province indicated that they possessed formal qualifications and 79% (15 respondents) from KwaZulu-Natal Province stated they were formally qualified.

Attitudes, opinions and perceptions of conservation practitioners

The GLMM examined differences between conservation practitioners per province and their responses, while the GIS attitude index provides a geographic distribution of conservation practitioner attitudes.

In response to the statements/questions posed in Table 2, the locations where conservation practitioners were employed did not predict attitudes and perceptions, although I found differences between the types of responses (Tables 3–4). Positive responses towards wildlife predominated (for two out of the three statements) (Table 3), and negative outcomes for wildlife were produced when practitioners more frequently disagreed that agriculture wastes natural habitats (Table 3). Positive attitudes towards wildlife related to Typology A (i.e. respondents' concern for the ecosystem (ecocentric values) and for Typology B (i.e. the aesthetic and economic value of wildlife). Negative attitudes towards wildlife related to Typology C (i.e. local people and community-conservation oriented interests).

Positive responses towards local human communities predominated in five out of the eight statements (Table 4), except for Statement 5 in which conservation practitioners more frequently agreed that 'Poachers are criminals', resulting in a negative outcome towards local people (positive for wildlife) (Table 4). Positive attitudes towards local human communities related to Typology C (i.e. local people and community-conservation oriented interests). Negative attitudes towards local human communities related to Typology D (i.e. disinterest

and indifference towards the socio-economic needs of local human communities) and Typology E (i.e. protectionist beliefs that biodiversity can only survive in isolation of anthropogenic disturbance) (Table 4). The output of the GLMM, comparing conservation practitioner responses, as well as the comparison of trichotomous responses, is included in **Supplementary material:** Tables S5–6 respectively.

Table 3. Conservation practitioners' attitudes and opinions towards wildlife for each statement/question to show the dominant response, dominant typology and corresponding outcome (negative, positive or neutral) (dependent factors) associated with each statement/question. Post-hoc letters represent the *P*-values of the linear mixed model generated in **Supplementary material:** Tables S5–6.

Statement/Question	**Proportion of conservation practitioners and their responses, with different post-hoc letters[abc] representing significant differences between responses**			**Dominant response**	**Dominant typology**	**Outcome**
	KwaZulu-Natal	**Limpopo**	**Mpumalanga**			
1. Wildlife plays a very important part in our ecosystem	100% Agreed[a]	94% Agreed[a]	100% Agreed[a]	Agree	A: Wildlife plays a very important part in our ecosystem	Positive
	0% Disagreed[b]	0% Disagreed[b]	0% Disagreed[b]			
	0% Unsure[b]	6% Unsure[b]	0% Unsure[b]			
2. Wildlife attracts ecotourism	100% Agreed[a]	100% Agreed[a]	100% Agreed[a]	Agree	B: Concern for the aesthetic and economic value of wildlife	Positive
	0% Disagreed[b]	0% Disagreed[b]	0% Disagreed[b]			
	0% Unsure[b]	0% Unsure[b]	0% Unsure[b]			
3. Agriculture wastes natural habitats	26% Agreed[a]	42% Agreed[a]	15% Agreed[a]	Disagree	C: Local people and community-conservation oriented interests	Negative
	48% Disagreed[b]	29% Disagreed[b]	47% Disagreed[b]			
	26% Unsure[a]	29% Unsure[a]	38% Unsure[a]			

Table 4. Conservation practitioners' attitudes and opinions towards local human communities for each statement/question to show the dominant response, dominant typology and corresponding outcome (negative, positive or neutral) (dependent factors) associated with each statement/question. Post-hoc letters represent the *P*-values of the linear mixed model generated in **Supplementary material:** Tables S5–6.

Statement/Question	**Proportion of conservation practitioners and their responses, with different post hoc letters[abc] representing significant differences between responses**			**Dominant response**	**Dominant typology**	**Outcome**
	KwaZulu-Natal	**Limpopo**	**Mpumalanga**			
4. Poverty is not my problem	16% Agreed[a]	18% Agreed[a]	31% Agreed[a]	Disagree	C: Local people and community-conservation oriented interests	Positive
	68% Disagreed[b]	71% Disagreed[b]	54% Disagreed[b]			
	16% Unsure[c]	11% Unsure[c]	15% Unsure[c]			
5. Poachers are criminals	79% Agreed[a]	71% Agreed[a]	100% Agreed[a]	Agree	D: Disinterest and indifference towards the socio-economic needs of local human communities E: Protectionist beliefs that biodiversity can only survive in isolation of anthropogenic disturbance	Negative
	16% Disagreed[b]	11% Disagreed[b]	0% Disagreed[b]			
	5% Unsure[b]	18% Unsure[b]	0% Unsure[b]			
6. Rural communities should benefit from tourism revenue	95% Agreed[a]	71% Agreed[a]	92% Agreed[a]	Agree	C: Local people and community-conservation oriented interests	Positive
	5% Disagreed[b]	6% Disagreed[b]	0% Disagreed[b]			
	0% Unsure[c]	23% Unsure[c]	8% Unsure[c]			
7. Educating communities will benefit the reserve	95% Agreed[a]	88% Agreed[a]	100% Agreed[a]	Agree	C: Local people and community-conservation oriented interests	Positive
	0% Disagreed[b]	6% Disagreed[b]	0% Disagreed[b]			
	5% Unsure[b]	6% Unsure[b]	0% Unsure[b]			

Statement/Question	Proportion of conservation practitioners and their responses, with different post hoc letters[abc] representing significant differences between responses			Dominant response	Dominant typology	Outcome
	KwaZulu-Natal	Limpopo	Mpumalanga			
8. Rural communities can make use of natural resources from/on the reserve	53% Agreed[a]	35% Agreed[a]	46% Agreed[a]	Agree	C: Local people and community-conservation oriented interests	Positive
	26% Disagreed[b]	35% Disagreed[b]	38% Disagreed[b]			
	21% Unsure[c]	30% Unsure[c]	16% Unsure[c]			

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Implementation of trans-boundary monitoring, environmental-education and community-engagement programmes

The number of 'yes' responses (indicating the implementation of trans-boundary monitoring, environmental-education (EE) and community-engagement (CE) programmes) prevailed over no responses, with a positive outcome towards conservation and protection of communities (Table 5). No significant differences existed between conservation practitioners per province regarding the implementation of trans-boundary monitoring and EE or CE programmes, although differences between types of responses existed (Table 5). Positive outcomes related to Typology C (i.e. local people and community-conservation oriented interests) for all three programmes. The output of the GLMM, comparing conservation practitioner responses as well as the comparison of trichotomous responses, is included in **Supplementary material:** Tables S7–8 respectively.

Table 5. Comparison of conservation practitioners' responses for each statement/question concerning trans-boundary monitoring, environmental-education and community-engagement programmes to show the dominant response, dominant typology and corresponding outcome (negative, positive or neutral) (dependent factors) associated with each statement/question. Post-hoc letters represent the *P*-values of the linear mixed model generated in **Supplementary material:** Table S7–8.

Statement or question	**Proportion of conservation practitioners and their responses, with different post hoc letters[abc] representing significant differences between responses**			**Dominant response**	**Dominant typology**	**Outcome**
	KwaZulu-Natal	**Limpopo**	**Mpumalanga**			
Implementation of trans-boundary monitoring	58% Yes[a]	65% Yes[a]	84% Yes[a]	Yes	C: Local people and community-conservation oriented interests	Positive
	5% No[b]	35% No[b]	8% No[b]			
	37% No response[b]	0% No response[b]	8% No response[b]			
Implementation of environmental-education programmes	89% Yes[a]	59% Yes[a]	38% Yes[a]	Yes	C: Local people and community-conservation oriented interests	Positive
	9% No[b]	35% No[b]	54% No[b]			
	0% No response[c]	6% No response[c]	8% No response[c]			
Implementation of community-engagement programmes	95% Yes[a]	59% Yes[a]	38% Yes[a]	Yes	C; Local people and community-conservation oriented interests	Positive
	5% No[b]	41% No[b]	54% No[b]			
	0% No response[c]	0% No response[c]	8% No response[c]			

Opinions of conservation practitioners regarding community-based-natural-resource management

The respondents were requested to give their opinion of CBNRM. The responses were open-ended, and the majority were positive to the idea. Of the 17 practitioners from Limpopo Province, 11 were positive towards CBNRM (65%), one respondent was negative (6%) and

five were unsure/neutral or gave no response (29%). Of the 13 practitioners from Mpumalanga Province, eight were positive towards CBNRM (62%), three respondents were negative (23%) and two were unsure/neutral or gave no response (15%). Of the 19 practitioners from KwaZulu-Natal Province, 12 were positive towards CBNRM (63%), one respondent was negative (5%) and six were unsure/neutral or gave no response (32%).

The following responses were chosen because they represent dichotomous views on CBNRM. A respondent from KwaZulu-Natal provided the following opinion for CBNRM: "Very important. Get the community to realise the role they play and their environmental impacts. People should know the reserve is there to assist them. Also sustainable utilisation—grass/muti". Muti refers to African traditional medicine derived from various natural products, predominantly indigenous plants (Drewes, 2012). Another respondent from the same area stated, "It would be better to promote paid sterilisation of community members than to promote subsistence in communities, which eventually becomes exploited in a neo-capitalistic society".

Geographic information system attitude index

Attitudes towards wildlife

The GIS attitude index towards wildlife highlights the predominant areas of low conservation concern (positive attitudes). The attitude index towards wildlife ranged from +6 to +1 (maximum +6) (Fig. 2). Interestingly, the highest negative attitude score towards wildlife were +1 out of a maximum negative score of −6 and were displayed by conservation practitioners from Manomba Nature Reserve in Giyani, Limpopo Province and Ezemvelo Nature Reserve in Mpumalanga Province (Fig. 2). The largest dark blue GPS data points (Fig. 2) highlight these areas of high conservation concern. The highest positive attitude scores towards local human communities were +6, the maximum positive that could be achieved, and were displayed by conservation practitioners near PAs adjacent to the Kruger National Park western border in Mpumalanga Province and in Ndumo Game Reserve in KwaZulu-Natal Province (Fig. 2). The smallest white GPS data points (Fig. 2) highlight these areas of low (positive) conservation concern. The overall cumulative mean attitude index for attitudes to wildlife was +3.98 (n = 49). (Score calculations are available in **Supplementary material:** Table S9).

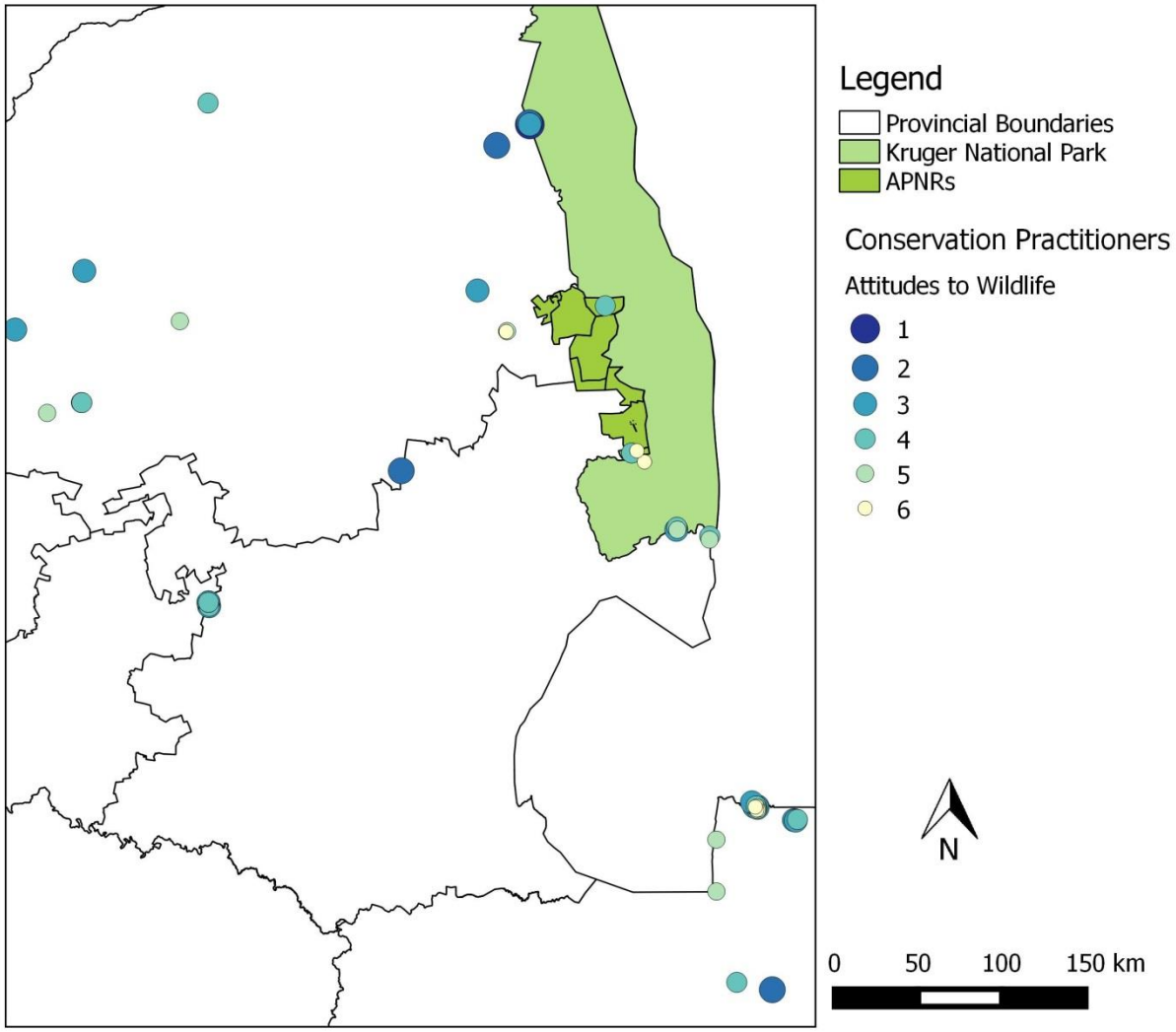


Figure 2. Comparison of geographic information system attitude index scores of conservation practitioners towards wildlife. Circles of various sizes are global positioning system data points that represent attitude index scores. Larger circles denote negative attitudes and smaller circles denote positive attitudes.

Attitudes towards local human communities

The GIS attitude index towards local human communities highlights areas of both low (positive attitudes) and high (negative attitudes) conservation concern. The higher the negative attitude index, the greater the potential for conflict between conservation authorities or wildlife and local human communities. The higher the positive attitude index, the greater the potential for collaboration between conservation authorities and local human communities, which demonstrates potential for community-conservation initiatives. The largest white GPS data points (Fig. 3) highlight areas of high concern. The highest negative attitude score towards local human communities was −4 out of a maximum negative score of

−10 and was displayed by conservation practitioners from Mkuze and Ezemvelo nature reserves in KwaZulu-Natal and Mpumalanga provinces respectively (Fig. 3).

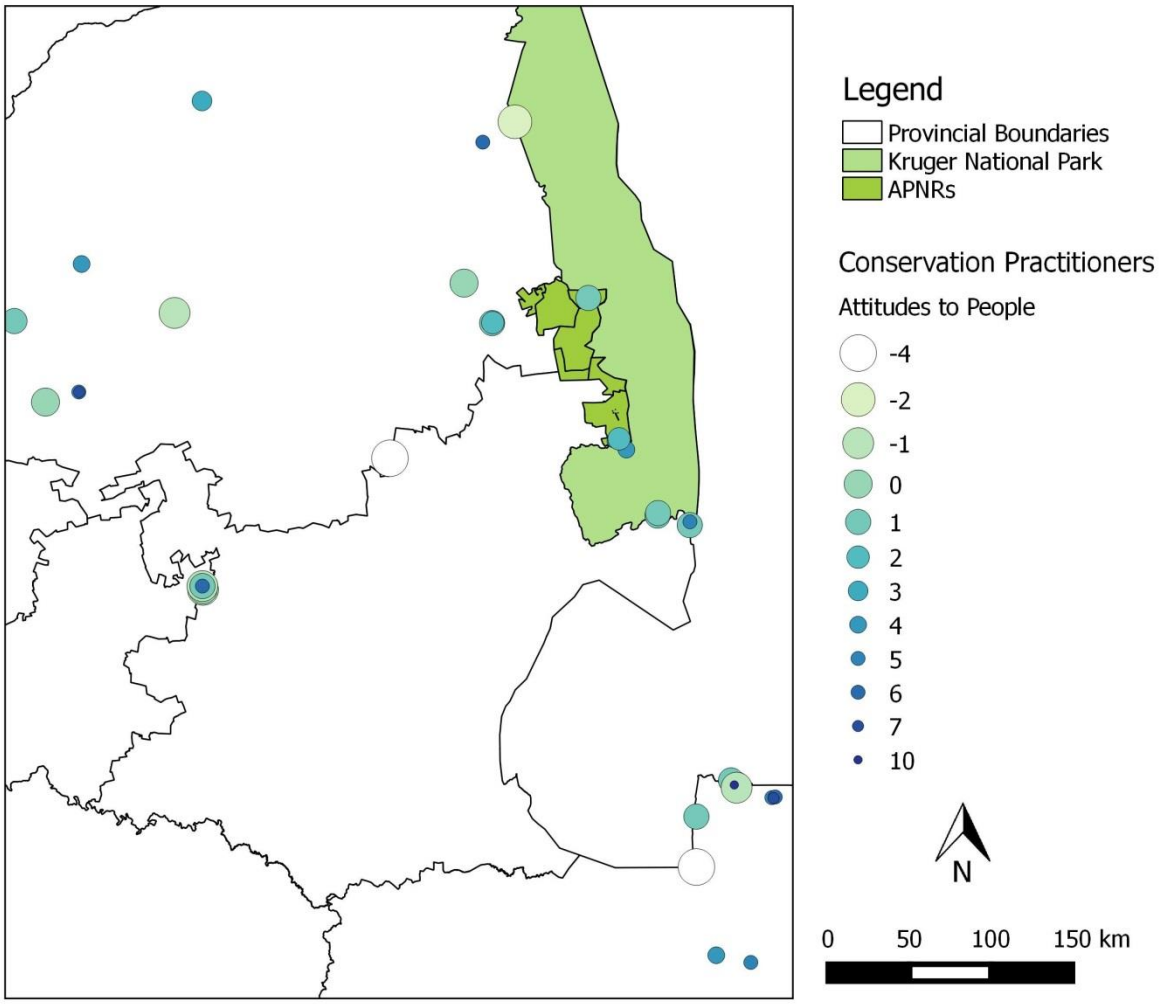


Figure 3. Comparison of geographic information system attitude index scores of conservation practitioners towards local human communities. Circles of various sizes are global positioning system data points that represent attitude index scores. Larger circles denote negative attitudes and smaller circles denote positive attitudes.

The smallest dark blue GPS data points (Fig. 3) highlight areas of low (positive) conservation concern. The highest positive attitude score towards local human communities was +10, the maximum positive score that could be attained by conservation practitioners, and emanated from Ndumo Game Reserve in KwaZulu-Natal Province (Fig. 3). Interestingly, high positive and high negative attitudes (GPS data points) overlapped at Ndumo Game Reserve, suggesting a difference in the views of practitioners employed at the same PA. The cumulative mean attitude index for attitudes to local human communities was +2.31 (n = 49). (Score calculations are available in **Supplementary material:** Table S10).

Discussion

This study sought to evaluate the attitudes and interactions of conservation practitioners towards wildlife and local human communities. I asked whether conservation practitioners would demonstrate more negative attitudes than positive attitudes towards local human communities because (under the assumption) local communities threaten the persistence of wildlife through a variety of practices, such as retaliatory or deliberate persecution of stray wildlife (Chapter 5), uncontrolled harvesting of natural resources from the park and poaching. A wide variety of languages, ethnicities and religions were prevalent among conservation practitioners, typical for the South African provincial demography (Statistics South Africa, 2007). In addition, subsistence farmers and conservation practitioners showed similar religious beliefs throughout the study sites. The majority of respondents indicated that they held formal qualifications in a related field of conservation.

Positive responses towards wildlife were associated with the ecocentric (Typology A), aesthetic and economic values (Typology B) of wildlife. Stoner et al., (2007) maintain that wildlife populations within large, fenced PAs are stable, thus mitigating indigenous habitat loss, poaching and disease. For example, population densities of a wide diversity of large mammals in Tanzania were considerably greater within PAs where illegal hunting prohibitions were implemented compared with reserves where unregulated hunting practices prevailed (Newmark, 2008). Other scholars argue however that isolating wildlife within fenced PAs to prevent poaching and disease, comes with a cost, i.e. increases in wildlife population sinks by limiting the dispersal of migratory wild animals (Newmark, 2008) and consequently plants (Van de Vijver et al., 1999).

Interestingly, negative attitudes to wildlife (positive for local human communities) were elicited because the majority of conservation practitioners disagreed that agriculture wastes natural habitats. Such responses were associated with Typology C (i.e. the community-conservation oriented interests of respondents). While conservation practitioners acknowledge that agriculture is required to sustain the human population, these views were controversial, as they simultaneously encourage indigenous habitat transformation and fragmentation.

It is noteworthy that negative responses towards local human communities pertained to typologies D and E (i.e. a disinterest and indifference towards the socio-economic needs of local human communities in addition to protectionist ideologies). Furthermore, conservation practitioners cited generally negative responses towards poachers, showing low tolerance to

factors that threaten biodiversity. According to Kennedy et al., (1994), poaching of even a few individuals of a population that occurs at naturally low densities, such as the black rhinoceros *Diceros bicornis* (Milner-Gulland and Leader-Williams, 1992) and the tiger *Panthera tigris* (Linkie et al., 2003) may increase the probability of localised extinction. Hence, the full protection of such vulnerable target species is a conservation priority for PA management (Linkie et al., 2003).

I also noted that most conservation practitioners agreed that local human communities should make use of the natural resources in the park. These agree responses were associated with community-conservation oriented interests of respondents that showed potential to enhance collaboration with PA authorities (Child, 1995). In addition, previous studies have shown that restrictions on the use of biological resources from reserves, such as medicinal florae, fuelwood, bush meat and grass for thatch and basketry from PAs, may intensify conflict between local communities and conservation authorities (Defries et al., 2007; DeGeorges and Reilly, 2009; Weladji and Tchamba, 2003). Many scholars caution, however, that stringent ecological monitoring is required to prevent natural resource over-exploitation and that the costs associated with permitting resource use by local communities should be examined carefully (Defries et al., 2007).

The cumulative mean attitude indices for wildlife (+3.98) and local human communities (+2.31) were positive, indicating generally that conservation practitioners held similar values for wildlife and local human communities. According to the GIS attitude index maps, Mkuze Game Reserve in KwaZulu-Natal Province and Ezemvelo Game Reserve in Mpumalanga Province were areas of high conservation concern since the most negative attitudes (−4 out of a maximum of −10) towards local human communities prevailed among conservation practitioners. According to some authorities (Anthony, 2007, Page et al., 2015) areas where negative attitudes persist, could represent high HWC spots, in addition to alienating local human communities from PA management. Anthony (2007) states that this could possibly manifest into threats targeted at wildlife, especially those species that are free ranging or have the ability to transgress PA boundaries (Anthony, 2007). Perhaps community outreach initiatives in these areas would be beneficial to improve communication between PA authorities and local communities (Archabald and Naughton-Treves, 2001).

Most respondents from all three provinces indicated that they implement trans-boundary monitoring. Previous studies have showed surveillance and monitoring of ecosystems significantly reduced human-wildlife conflicts and decreases illegal snaring and poaching (Danielsen et al., 2003; Gray and Kalpers, 2005; Linkie et al., 2003). Hence, trans-

boundary monitoring could potentially play a fundamental role in mitigating HWC in north-eastern South Africa. Future studies must verify the scale and application of trans-boundary monitoring reported in my study.

Most respondents from all three provinces indicated that they implement environmental-education and community-engagement programmes. Education programmes designed to reduce human-bear *Ursus americanus* conflicts in Colorado, United States of America, by increasing awareness of anthropogenic behaviour that increases conflict and reduces lethal control, showed reductions in complaints of human-bear conflict (Gore et al., 2006). Similarly, another study in China showed that environmental-education programmes designed to reduce human-elephant *Elephas maximus* conflict by increasing human safety awareness and developing technical skills to build deterrent, ecological-friendly structures such as trenches and salt pools around crops, reduced human-elephant conflict (Zhang and Wang, 2003). Hence, environmental-education programmes, tailored to reduce conflict, develop awareness, modify anthropogenic behaviour and encourage wildlife tolerance, could potentially play a fundamental role in mitigating HWC (Gore et al., 2006; Zhang and Wang, 2003). Again, future studies must verify the scale and application of environmental education programmes reported in my study.

The majority of respondents were positive about the idea of CBNRM, indicating that the assumption of a progressive shift from historic protectionist-conservation approaches to people-oriented conservation (Nepal, 2002) could be plausible. The positive opinions regarding CBNRM in my study concur with another survey conducted in western Uganda in which the majority of the respondents (staff at Uganda Wildlife Authority) thought that tourism revenue-sharing and programmes promoting sustainable resource-use had improved attitudes of community members (defined by friendlier relations between local human communities and PA management; Archabald and Naughton-Treves, 2001). Moreover, sharing tourism revenue reduced conflict between park management and local human communities, decreased illegal activity, such as poaching, and increased local community participation in PA management (Archabald and Naughton-Treves, 2001). Community-based-natural-resource management, however, should be practised with strict guidelines because ecological realities cannot be overlooked, especially for endangered species and large bodied mammals such as carnivores and mega-herbivores, which, because of their low reproductive rates, require isolation from anthropogenic landscapes due to the high risk of poaching and HWC (Locke and Dearden, 2005). In addition, it is important to note that people will only report what they feel comfortable with (positive attitudes), as with all

questionnaire surveys, and hence the results should always be interpreted with some caution (Dickman, 2012).

Conclusions

Conservation practitioners harboured mixed attitudes and opinions towards wildlife and local human communities. My findings also showed that a variety of typologies were associated with positive and negative attitudes towards local communities. While positive attitudes have the potential to create synergies between conservation practitioners and local human communities, the reasons for the negative and mixed responses require further research to understand the underlying reasons for such responses. My study did not provide universally similar attitudes among the respondents, which is expected given individual human experiences and cultural tenets. However, this is the first study to examine the attitudes of conservationists in three provinces in SA in the context of previous (Khan, 1994) and ongoing marginalisation of rural black communities, isolated from conservation practices (Cock and Fig, 2000). Nonetheless, the present study provides avenues for future research by investigating the underlying reasons for the attitudes and opinions of PA managers, which might support HWC mitigation.

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6181

Supplementary material

Table S1. Language of respondents/participants.

Locality	Language		
	Type	**Number**	**%**
Limpopo	Afrikaans	3	17.6
	English	5	29.4
	Ndebele	1	5.9
	Sotho	1	5.9
	Other	1	5.9
	Tsonga	5	29.4
	Zulu	1	5.9
Mpumalanga	Afrikaans	1	7.7
	English	5	38.5
	Ndebele	1	7.7
	Other	2	15.4
	Sotho	2	15.4
	Venda	1	7.7
	Zulu	1	7.7
KwaZulu-Natal	Afrikaans	4	21.1
	English	3	15.7
	Other	1	5.3
	Zulu	11	57.9

Table S2. Ethnicity of respondents/participants.

Locality	Ethnicity		
	Type	**Number**	**%**
Limpopo	Ndebele	1	5.9
	Other	6	35.3
	Sotho	2	11.8
	White	7	41.1
	Zulu	1	5.9
Mpumalanga	Ndebele	1	7.7
	No response	1	7.7
	Other	2	15.4
	Sepedi	1	7.7
	Sotho	1	7.7
	Venda	1	7.7
	White	5	38.5
	Zulu	1	7.7
KwaZulu-Natal	White	6	31.6
	Other	2	10.5
	Zulu	11	57.9

Table S3. Religious affiliation of respondents/participants.

Locality	Religion		
	Type	**Number**	**%**
Limpopo	Christian	15	88.2
	No religion	1	5.9
	Zionist	1	5.9
Mpumalanga	Catholic	2	15.4
	Christian	4	30.7
	Lutheran	1	7.7
	No religion	3	23.1
	Other	1	7.7
	Zionist	2	15.4
KwaZulu-Natal	Catholic	3	15.7
	Christian	11	57.9
	Other	1	5.3
	Pentecostal	1	5.3
	Zionist	3	15.7

Table S4. Number and percentage of respondents/participants who claimed to have formal education in the field of conservation.

Province	Formal qualification in Conservation or related field	
	Number	%
Limpopo (n = 17)	17	100
Mpumalanga (n = 13)	9	69
KwaZulu-Natal (n = 19)	15	78.9

Table S5. Output of a generalised linear mixed model by maximum likelihood, comparing response of conservation practitioners (fixed factors) in each province for each statement/question.

Statement or question	Generalised linear mixed model fit by maximum likelihood				Coefficient estimates for correlation of variables			
	Comparisons	**Higher affected variable**	**Covariate 1**	**Covariate 2**	**df**	**Std. Error**	**Z value**	***P***
1. Wildlife plays a very important part in our ecosystem	KZN vs Limpopo	No difference	Percentage of responses	Location	5	0.14	0.36	0.72
	KZN vs Mpumalanga					0.14	0.36	0.72
	Limpopo vs Mpumalanga					0.14	0.00	0.99
2. Wildlife attracts ecotourism	KZN vs Limpopo				5	0.14	0.00	0.99
	KZN vs Mpumalanga					0.14	0.00	0.99
	Limpopo vs Mpumalanga					0.14	0.00	0.99
3. Agriculture wastes natural habitats	KZN vs Limpopo				5	0.14	0.00	0.99
	KZN vs Mpumalanga					0.14	0.00	0.99
	Limpopo vs Mpumalanga					0.14	0.00	0.99
4. Poverty is not my problem	KZN vs Limpopo				5	0.14	0.07	0.94
	KZN vs Mpumalanga					0.14	0.00	0.99
	Limpopo vs Mpumalanga					0.14	0.07	0.94
5. Poachers are criminals	KZN vs Limpopo				5	0.14	0.07	0.94
	KZN vs Mpumalanga					0.14	0.00	0.99
	Limpopo vs Mpumalanga					0.14	0.07	0.94

Statement or question	Generalised linear mixed model fit by maximum likelihood				Coefficient estimates for correlation of variables			
	Comparisons	**Higher affected variable**	**Covariate**	**Random factor**	**df**	**Std. Error**	**Z value**	***P***
6. Rural communities should benefit from tourism revenue	KZN vs Limpopo	No difference	Percentage of responses	Location	5	0.14	0.07	0.94
	KZN vs Mpumalanga					0.14	-0.07	0.94
	Limpopo vs Mpumalanga					0.14	0.14	0.88
7. Educating communities will benefit the reserve	KZN vs Limpopo				5	0.14	0.36	0.72
	KZN vs Mpumalanga					0.14	0.36	0.72
	Limpopo vs Mpumalanga					0.14	0	0.99
8. Rural communities can make use of natural resources from/on the reserve	KZN vs Limpopo				5	0.14	-0.07	0.72
	KZN vs Mpumalanga					0.14	-0.07	0.72
	Limpopo vs Mpumalanga					0.14	0	0.99

6194

Table S6. Output of a generalised linear mixed model by maximum likelihood, comparing trichotomous responses to show the dominant response (dependent factors) for each statement.

Generalised linear mixed model fit my maximum likelihood			Coefficient estimates for correlation of fixed effects			
Statement/Question	**Comparison of responses**	**Dominant response**	**df**	**Std. Error**	**Z value**	***P***
1. Wildlife plays a very important part in our ecosystem	Agree vs disagree	Agree	3	0.36	6.97	< 0.001
	Agree vs unsure			0.36	6.97	< 0.001
	Disagree vs unsure			0.58	0	0.99
2. Wildlife attracts ecotourism	Agree vs disagree	Agree	5	0.41	-9.49	< 0.001
	Agree vs unsure			0.41	-9.49	< 0.001
	Disagree vs unsure			0.58	0	0.99
3. Agriculture wastes natural habitats	Agree vs disagree	Disagree	5	0.14	2.78	0.005
	Agree vs unsure			0.15	0.83	0.41
	Disagree vs unsure			0.14	1.97	0.049
4. Poverty is not my problem	Agree vs disagree	Disagree	5	0.14	7.59	< 0.001
	Agree vs unsure			0.2	-2.1	0.036
	Disagree vs unsure			0.17	8.9	< 0.001
5. Poachers are criminals	Agree vs disagree	Agree	5	0.2	-10.99	< 0.001
	Agree vs unsure			0.21	-10.95	< 0.001
	Disagree vs unsure			0.28	0.7	0.49
6. Rural communities should benefit from tourism revenue	Agree vs disagree	Agree	5	0.31	-10.25	< 0.001
	Agree vs unsure			0.19	-11.15	< 0.001
	Disagree vs unsure			0.35	-2.95	0.003
7. Educating communities will benefit the reserve	Agree vs disagree	Agree	5	0.41	-9.34	< 0.001
	Agree vs unsure			0.41	-9.34	< 0.001
	Disagree vs unsure			0.58	0	0.99
8. Rural communities can make use of natural resources from/on the reserve	Agree vs disagree	Agree	5	0.13	-2.28	0.022
	Agree vs unsure			0.15	-4.79	< 0.001
	Disagree vs unsure			0.16	2.64	0.008

6199 **Table S7.** Output of a generalised linear mixed model by maximum likelihood, comparing response of conservation practitioners (fixed factors)
6200 in each province regarding trans-boundary monitoring, environmental-education and community-engagement programmes.
6201

Statement/Question	Generalised linear mixed model fit by maximum likelihood				Coefficient estimates for correlation of variables			
	Comparisons	Higher affected variable	Covariate	Random factor	df	Std. Error	Z value	*P*
Implementation of trans-boundary monitoring	KZN vs Limpopo	No difference	Percentage of responses	Location	5	0.14	-0.07	0.94
	KZN vs Mpumalanga					0.15	0	0.99
	Limpopo vs Mpumalanga					0.14	0.71	0.94
Implementation of environmental-education programmes	KZN vs Limpopo				5	0.14	0	0.99
	KZN vs Mpumalanga					0.14	0	0.99
	Limpopo vs Mpumalanga					0.14	0	0.99
Implementation of community-engagement programmes	KZN vs Limpopo				5	0.14	0	0.99
	KZN vs Mpumalanga					0.14	0	0.99
	Limpopo vs Mpumalanga					0.14	0	0.99

Table S8. Output of a generalised linear mixed model by maximum likelihood, comparing trichotomous responses regarding trans-boundary monitoring, environmental-education and community-engagement programmes to show the dominant response (dependent factors) for each statement/question.

Generalised linear mixed model fit my maximum likelihood				**Coefficient estimates for correlation of fixed effects**		
Statement/Question	**Comparison of responses**	**Dominant response**	**df**	**Std. Error**	**Z value**	***P***
Implementation of trans-boundary monitoring	Agree vs disagree	Agree	5	0.16	-9.19	< 0.001
	Agree vs unsure			0.16	-9.34	< 0.001
	Disagree vs unsure			0.21	-0.31	0.76
Implementation of environmental-education programmes	Agree vs disagree	Agree	5	0.12	-5	< 0.001
	Agree vs unsure			0.28	-9.33	< 0.001
	Disagree vs unsure			0.28	-6.89	< 0.001
Implementation of community-engagement programmes	Agree vs disagree	Disagree	5	0.12	-5.29	< 0.001
	Agree vs unsure			0.36	-8.81	< 0.001
	Disagree vs unsure			0.37	-6.87	< 0.001

Table S9. Calculation of attitude index scores for attitudes of conservation practitioners towards wildlife.

Attitudes to wildlife		
Wildlife plays a very important part in our ecosystem	Wildlife attracts ecotourism	Agriculture wastes natural habitats
+2 SA; 1 A; 0 U; −1 D; −2 SD	+2 SA; 1 A; 0 U; −1 D; −2 SD	+2 SA; 1 A; 0 U; −1 D; −2 SD
+2 Strongly agree	+2 Strongly agree	+2 Strongly agree
+1 Agree	+1 Agree	+1 Agree
0 Unsure	0 Unsure	0 Unsure
−1 Disagree	−1 Disagree	−1 Disagree
−2 Strongly disagree	−2 Strongly disagree	−2 Strongly disagree

6212 **Table S10.** Calculation of attitude index scores for attitudes of conservation practitioners
6213 towards local human communities.
6214

Attitudes to local human communities				
Poverty is not my problem	**Rural communities should benefit from tourism revenue**	**Educating communities will benefit the reserve**	**Poachers are criminals**	**Rural communities make use of natural resources**
−2 SA; −1 A; 0 U; 1 D; 2 SD	+2 SA; 1 A; 0 U; −1 D; −2 SD	+2 SA; 1 A; 0 U; −1 D; −2 SD	−2 SA; −1 A; 0 U; +1 D; +2 SD	+2 SA; 1 A; 0 U; −1 D; −2 SD
+2 Strongly agree	+2 Strongly agree	+2 Strongly agree	-2 Strongly agree	+2 Strongly agree
+1 Agree	+1 Agree	+1 Agree	−1 Agree	+1 Agree
0 Unsure	0 Unsure	0 Unsure	0 Unsure	0 Unsure
−1 Disagree	−1 Disagree	−1 Disagree	1 Disagree	−1 Disagree
−2 Strongly disagree	−2 Strongly disagree	−2 Strongly disagree	2 strongly disagree	−2 Strongly disagree

CHAPTER EIGHT

Life on the edge: farmer-African wild dog *Lycaon pictus* conflict in north-eastern South Africa

Abstract

In recent decades, natural habitat reduction and persecution by farmers have caused substantial declines in African wild dog *Lycaon pictus* populations, with viable populations (>8 adults) being limited to less than 20% of its former geographic range. The aim of my study was to generate maps of conflict depicting farmer-wild dog conflict hot spots in four wild dog packs in the Waterberg Biosphere network and the south-western border of the Kruger National Park, South Africa. One individual per pack was collared using satellite- or radio-tracking collars. Using data from the collars and farmer questionnaires, I identified areas where the home ranges of African wild dogs intersected with lethal-controlling farmers, using minimum convex polygons and assessed whether or not a pack's core areas of utilisation overlapped with lethal-controlling farmers. This was performed by using African wild dog heat maps, generated through kernel density estimations and represented by dense clustering of the GPS points of a pack. The free-ranging Waterberg pack displayed the largest home range (1 345 km^2), followed by the packs within the Kruger National Park (Ditsala: 797 km^2; Orpen: 363 km^2) and then the free-roaming (in the Hoedspruit area) Guernsey pack (351.59 km^2). Minimum convex polygons of the Ditsala and Waterberg packs overlapped with farmers that reported using lethal control. Kernel density estimations of the Ditsala pack indicated that the pack spent a large proportion of time near reserve edges with overlap between clustered African wild dog and farmer global positioning system points. Kernel density estimations of the Waterberg pack indicated that the pack avoided farmers, utilising pockets of scrub and woodland areas of Waterberg as refugia. I conclude that the wide-ranging behaviour of African wild dogs increased their contact with anthropogenic activity with farms located on border edges, which represent African wild dog population sinks. Nonetheless, the Waterberg pack demonstrated avoidance of most farmers by a greater use of vegetation thickets.

Keywords: home-range size, human-wildlife conflict, kernel density estimations, lethal control, wide-ranging behaviour

Introduction

The African wild dog (hereafter, wild dog) *Lycaon pictus* (Temmink, 1820) is one of the most threatened and endangered canids in Sub-Saharan Africa (Ginsberg and Macdonald, 1990; Lindsey et al., 2004; IUCN, 2012). Wild dogs have been extirpated from 28 African countries in which they were formerly recorded (Fanshawe et al., 1997; Lindsey et al., 2004), translating into an 80% reduction in their historic geographic range. In the 18th century, government-sponsored eradication movements targeted several carnivores that were perceived as vermin, including wild dogs (Creel and Creel, 2002; Woodroffe et al., 2005). These unregulated vermin-control campaigns continued until the end of the last century (Creel and Creel, 2002; Woodroffe et al., 2005) under the misconception that wild dogs were cruel to disembowel live prey, and they suppressed antelope numbers (Creel and Creel, 2002). In recent decades, agricultural expansion, natural habitat reduction (Creel and Creel, 2002) and farmer persecutions (Rasmussen, 1999; Woodroffe, 2011) continue to elicit wild-dog population declines.

Currently, in Sub-Saharan Africa, viable wild dog populations that are genetically diverse occur in Botswana, Kenya, Mozambique, Namibia, north-eastern South Africa and Zimbabwe (Fanshawe et al., 1997; Woodroffe et al., 2005) and are afforded legal protection in most of these countries, except for Mozambique and Namibia (Creel and Creel, 2002). In South Africa, wild dogs have been limited to a single viable population (populations with ≥ eight packs that can persist without conservation intervention) in the Kruger National Park (KNP), the largest protected area (PA) in South Africa (Fanshawe et al., 1997, Mills et al., 1998). Presently, there are less than 450 wild dogs left in South Africa (Kelly Marnewick, Pers. Comm.), including individuals in the KNP, fenced game reserves and outside PAs, rendering this species severely vulnerable to extinction.

Habitat fragmentation is particularly prominent in South Africa (Lindsey et al., 2005) and hence, the KNP is the only PA large enough to house viable wild dog populations. Wild dogs not ranging in the KNP (e.g. Hluhluwe-iMfolozi, Mkuze, and Tembe Game Reserves, KwaZulu-Natal Province; Mapungubwe National Park, Limpopo Province; Madikwe Game Reserve and Pilanesburg National Park, North-West Province and Tswalu Kalahari Reserve, Northern Cape Province) are managed as isolated meta-populations (local breeding sub populations) in smaller PAs (Mills et al., 1998). Habitat loss and fragmentation have particularly adverse effects on wild dogs because wild dogs possess the largest home range (an area over which an animal travels that includes all the resources the animal requires to survive and reproduce) among all carnivores (Woodroffe and Ginsberg, 1998) and require PAs large enough to meet their home-range

requirements (Mills et al., 1998). Woodroffe and Ginsberg (1998) also postulated that carnivores with larger home ranges were more likely to become extinct than those with smaller home ranges. They also suggested that wide-ranging carnivore behaviour increased contact with anthropogenic activity on PA borders or edges, areas where high human-induced carnivore mortality can be expected (i.e. the edge effect; Woodroffe and Ginsberg, 1998).

Free-ranging or free-roaming wild dogs, in contrast to packs within PAs, are especially vulnerable in anthropogenic-dominated landscapes (Woodroffe, 2011) such as farms. Wide-ranging behaviour could predispose wild dogs to fortuitous threats, for example, road deaths or deliberate persecution from farmers (Woodroffe, 2011). In addition, the disappearances of corridors that link habitat patches in anthropogenic environments contribute to wild dog vulnerability (Woodroffe, 2011) by isolating some populations or exposing dispersing individuals to snares (Woodroffe and Ginsberg, 1998), poison and domestic animal-borne diseases (Creel and Creel, 2002). Free-ranging wild dogs on farmland face an increased risk of conflict with pastoralists (Woodroffe et al., 2005), particularly when adequate livestock protection such as livestock-fenced pens are absent (Woodroffe, 2011). In addition, wild dogs are diurnal hunters, making them conspicuous, increasing the probability of encounters with people (Creel and Creel, 2002).

Wild dogs are phylogenetically distinct and are the only extant species in the genus *Lycaon* (Girman et al., 1993). They are comparatively small, weighing 19–30 kg (Creel, 2001). Wild dogs are obligate cooperative breeders, living in cohesive hunting packs of two to twenty individuals (Creel and Creel, 2002), where males outnumber females in a 3:1 ratio (Mills et al., 1998). Separate dominance hierarchies for females and males exist, usually with the oldest breeding pair leading the group (Creel and Creel, 2002).

Through questionnaire interviews in selected localities in Waterberg and the south-western border of the KNP (Chapter 5), I demonstrated that wild dogs were among the top three ranking carnivores for the highest number of reported depredation incidences. It is, therefore, likely that attitudes among farmers and other landowners towards wild dogs in these areas are negative and could present a human-wild dog conflict hot spot.

Kruger National Park conservation and veterinary authorities monitor wildlife permeability and damage to fences along the western boundary fence of the KNP (Ferguson et al., 2012) and contain foot and mouth disease within the park (Jori et al., 2011). The western perimeter fence differs in strength and structure to manage or buffer different intensities and sources of damage (Jori et al., 2011). The KNP perimeter fences have become permeable due to flooding and the fence-pushing behaviour of bull elephants *Loxodonta africana* (Ferguson et al.,

2012). In addition, older fences without electric power on the western border have become the most permeable to wildlife, especially to elephants and carnivores (Ferguson et al., 2012).

Due to the wide-ranging behaviour of wild dogs (Woodroffe and Ginsberg, 1998) and their long-distance movements within the KNP (Fuller et al., 1992), as well as gaps in the border fences (Ferguson et al., 2012), it is likely that wild dog individuals may frequently use unprotected areas adjacent to the KNP. In these areas, anthropogenic threats may have negative consequences for these wild dog packs (Woodroffe and Ginsberg, 1998). Watermeyer (2012) showed that the survival of wild dogs that transgressed the KNP boundaries depended on improving farmer perception and tolerance outside these PAs.

There is evidence that free-ranging wild dogs from parts of Sub-Saharan Africa have recolonised in parts of Zimbabwe and north-eastern South Africa in the last century (Lindsey et al., 2005). The Waterberg pack could have descended from such wild dog immigrants, because they are a genetically distinct population occurring naturally in the area. Furthermore, the Waterberg pack is genetically unrelated to the KNP packs and hence is a conservation priority species (Thorn et al., 2013). The Waterberg Biosphere in Limpopo Province, South Africa comprises a network of commercial game-livestock farms and PAs (Thorn et al., 2013) where conflict encounters between wild dogs and farmers are common (Thorn et al., 2013). According to Thorn et al., (2013), farmers reportedly killed over 300 carnivores (mostly black-backed jackal *Canis mesomelas*, followed by brown hyena *Hyaena brunnea*, wild dog, leopard *Panthera pardus* and caracal *Caracal caracal*) over a one-year period within the Waterberg Biosphere network. Although a large number of wild dogs were not reportedly killed (Thorn et al., 2013), the Waterberg farmers still perceived wild dogs as a great threat to their livestock and game populations, although wild dogs were only responsible for a small percentage (<7%) of reported livestock depredations (Thorn et al., 2013). Hence, the persistence of these free-ranging wild dogs might depend on the attitudes and behaviour of landowners and livestock farmers.

In this study, I compared the movement patterns of wild dogs within and outside PAs that intersected with farmers who reportedly used lethal control, in order to establish whether or not core areas of home ranges of wild dogs' overlap with conflict hot spots. I generated maps of conflict depicting farmer-wild dog conflict hot spots using satellite-tracked or radio-collared wild dog packs and farmer questionnaire data in the Waterberg Biosphere network and the south-western border of the KNP, South Africa. The specific objectives were: 1) to define the home ranges of four wild dog packs (two free-roaming packs and two packs within the KNP) using minimum convex polygons; and 2) to assess whether or not wild dog core areas of utilisation overlap with farmers that reported implementing lethal control using wild dog heat

maps (areas of dense use). I predicted that free-ranging wild dogs would experience greater overlap with anthropogenic threats than individuals living within PAs. It may be that free-ranging wild dog individuals display larger home ranges and, therefore, are at greater risk of interacting with farmers.

Materials and methods

Study sites

This study took place at selected locations within the savannah biome of two provinces, namely Limpopo and Mpumalanga, South Africa (Fig. 1), where wild dog individuals of four different packs were collared. Two of these individuals ranged within the western border of the KNP (central global positioning system (GPS) co-ordinates of the study area ranged from -24,126; 31,464 to -25,185; 31,475), while the remaining two collared individuals free ranged in the Hoedspruit (-24,267; 31,013) and Waterberg (-23,674; 27,399) areas (Fig. 1; Tables 1-2).

Table 1. Wild dog collar details of four individuals that were satellite or global positioning system-ultra-high frequency tracked.

Pack name	Free-roaming or PA bound	Date collared	First date	Last date	Total	Collar type
Ditsala	KNP PA bound	2013/11/22	2013/11/22	2014/02/10	3 months	UHF GPS
Guernsey	Free-roaming	2014/05/30	2014/05/31	2015/06/25	12 months	Satellite
Orpen	KNP PA bound	2015/01/27	2015/01/28	2015/06/27	6 months	Satellite
Waterberg	Free-roaming	2013/11/21	2013/11/22	2014/03/12	5 months	UHF GPS

Table 2. Wild dog demographic details of four individuals that were tracked.

Pack name	Sex	Age	Pack size	Adults	Pups
Ditsala	Female	3 years	9	4	5
Guernsey	Male	3 years	6	6	unknown
Orpen	Male	4 years	32	~17	15
Waterberg	Male	1 year	~7	7	unknown

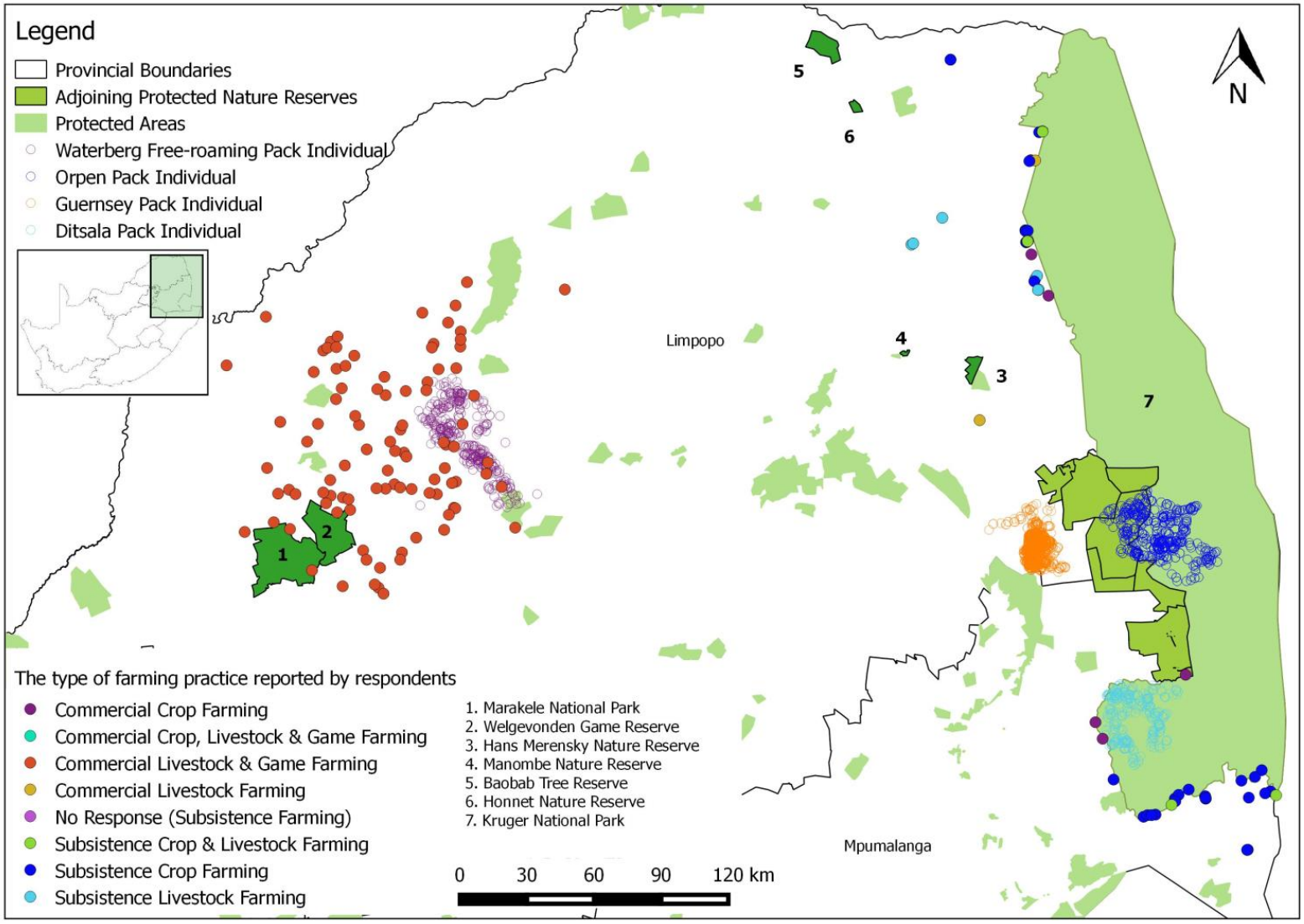


Figure 1. The four collared wild dogs and their distribution in relation to subsistence and commercial farming practices of respondents that participated in the questionnaire survey. A description of coloured and clear circles representing global positioning system data points is included in the map legend and index. Numbers represent key protected areas in the study site. A map of South Africa is provided in the inset.

A mixture of sour bushveld, thorn thickets and bushwillow woodland predominates in the south-western border of the KNP (Chirima et al., 2012), and Mopane woodland, knob thorn-marula savannah and bushwillow woodland vegetation prevails on the western border of the KNP (Chirima et al., 2012), where collaring occurred. The Waterberg is characterised by mountain and sandy bushveld veld types (Mucina and Rutherford, 2006) with pockets of scrub and woodland (Thorn et al., 2013). The Hoedspruit area is typified by granite lowveld and sour bushveld vegetation (Mucina and Rutherford, 2006). These localities are also neighboured by abundant commercial and subsistence crop farms, including livestock and game pasturage with mixed farming practices (Fig. 1).

Data collection

Data for this study were extracted from satellite-tracked or radio-collared wild dogs (Table 1). For territorial, group-living canids, home ranges of individuals accurately reflect those of the group (Kamler et al., 2012; Shivik and Gese, 2000), which is particularly appropriate for the cohesive pack structure of wild dogs. Lethal-control data were extracted from survey responses to the questionnaire used in Chapter 3, and detailed methodology concerning data collection, sampling procedures, interview methods and plotting of commercial and subsistence farmer GPS points is provided in Chapter 3. Farmer attitude index scores were derived from the same index generated in Chapter 6.

Permission to collar and radio or satellite-track these wild dog individuals were granted through a collaborative agreement with the Endangered Wildlife Trust (EWT): Carnivore Conservation Programme (CCP), a registered project with South African National Parks (SANParks). Veterinarians from SANParks carried out all wild dog immobilisations and veterinary interventions, while experienced EWT staff, in collaboration with SANParks' veterinarians, randomly selected and collared the wild dog individuals. Two types of collars were used due to EWT specifications and funding constraints.

<u>Global positioning system-ultra high frequency collars</u>

The global positioning system-ultra high frequency (GPS-UHF) collars, manufactured by Vectronic Aerospace, allowed for remote sensing of the collared individual's position and stored movement readings at four fixes per day. Ditsala and Waterberg pack collar data were stored in a subscriber identity module (SIM) card, a portable memory chip within the collar unit. An ultra-high frequency (UHF) handheld download unit was used to transfer the data from the collar SIM via the proximal download method. This method required the user to be positioned within

relatively close proximity of the collared individual (1.5 to 2 km depending on surrounding vegetation and topography if the user was on the ground or up to 10 km if aerial tracking was conducted, flying at a minimum height of 150 m). A UHF link was then established with the collar, and data were transferred to the UHF handheld unit, which was later connected to a computer for data copying. Hence, no animal immobilisation was required for data transfer. Accuracy of animal GPS locations can sometimes vary from 100 m to about 2 km for this collar system.

Iridium satellite collars

Iridium satellite wild dog collars (model G5C 275 D, manufactured by Sirtrack Ltd) were used to collar the Guernsey and Orpen individuals. The collar unit acted as a transmitter and sent data to a receiver (satellite), which relayed information to a central recording beacon on Earth. These data were then available on the Sirtrack website and set up for direct delivery to user email inbox. Accuracy of animal GPS locations can sometimes vary from 100 m to a few kilometres with satellite telemetry.

Data analysis

Collar data were downloaded onto Excel files, which were saved as comma-separated values files (.csv) for analysis in Quantum Geographic Information System (QGIS) version 2.8.1. The wild dog collar number, the latitude and longitude co-ordinates in decimal degrees and the date and time were saved in the csv file. Files were imported into QGIS for map construction, with each collar as its own csv data file. Shape files of PA and vegetation rasters were obtained from the South African National Biodiversity Institute (SANBI), Biodiversity geographic information system (BGIS) database (http://bgis.sanbi.org/nba/terrestrial_formalprotecedareas.asp). The shape file was used as a base layer and opened first, onto which collar data and questionnaire data were overlaid.

Calculations of home-range size using minimum convex polygons

To account for autocorrelation (i.e. very short sampling intervals that encourage lack of independence among observations and promote bias in home-range estimates), sampling intervals or fixes were set at six-hour intervals per day for all collars, according to the guidelines set by De Solla et al., (1999). This sampling interval maintained an adequate sample size for a highly mobile and wide-ranging species (Woodroffe and Ginsberg, 1998).

Home-range size and core areas of utilisation for each pack were calculated using 96% and 50% minimum convex polygons (MCPs) respectively. Minimum convex polygons were determined by the Animal Movement extension (AniMove; Hooge and Eichenlaub, 1997) in QGIS. The area of the home range and the core (50% MCPs) area (spaces of concentrated utilisation within the larger home range) were calculated using the measuring tool in QGIS, and the values were produced in km^2. The 96% MCP method is a common technique to fit estimated home ranges to actual territories for canids (e.g. coyote *Canis latrans*; Kamler et al., 2012). The MCP method is a suitable technique for determining core and home-range size for the wild dog (Jackson et al., 2012). Lethal-control data and farmer attitude index scores were extracted from survey responses to the questionnaire used in Chapter 3 (Appendix I) and were laid over the MCPs. This set up allowed me to assess whether or not wild dog core areas of utilisation overlapped with lethal-controlling and hostile farmers.

Heat maps using kernel density estimations

Kernel density estimations (KDEs) were used to generate 'heat' maps (core areas of intense or dense utilisation) in ArcMap version 10.2.2. (Redlands: ESRI Inc., 2006). Kernel density estimations are contouring methods for estimating probability density distributions using, in my case, multiple epicentres of wild dog activity that are independent of outlying points and, therefore, are minimally influenced by distant data points (Hemson et al., 2005). Kernel density estimations were created using distribution points of each pack to generate isopleths of intensity of utilisation by calculating the mean influence of data points at grid intersections (Hemson et al., 2005). These clustering of data points were displayed as a colour-ramped surface on a map where darker shades around certain areas denote higher densities of GPS points (Hemson et al., 2005). Hence, KDEs show the proportion of time spent in different parts of the home range. The GPS points of lethal-control data were extracted from survey responses to the questionnaire used in Chapter 3 (Appendix I) and laid over the MCPs. This illustrated whether or not wild dog areas of dense utilisation coincided with lethal-controlling farmers.

Results

The Waterberg free-ranging pack demonstrated the largest home range, followed by the Ditsala, Orpen and Guernsey packs (Table 3). The Orpen pack had the largest pack size (n = 17)

(Table 3). The Orpen pack made excursions outside the KNP border into adjacent PAs (Fig. 2). The Ditsala pack made excursions to the KNP south-western border (Fig. 3).

Table 3. Home (96%) and core (50%) range size represented in km^2 of four wild dogs from the Kruger National Park (Ditsala, Orpen and Guernsey) and Waterberg areas.

Individual	Home range (96%) (km^2)	Core area (50%) (km^2)	Edge visits
Ditsala	796.52	396.47	PA KNP and visits to the edge
Guernsey	351.59	54.50	Free roaming outside PA
Orpen	363.02	1328.16	PA KNP with visits to adjacent PAs
Waterberg	1345.39	517.57	Free roaming outside PA

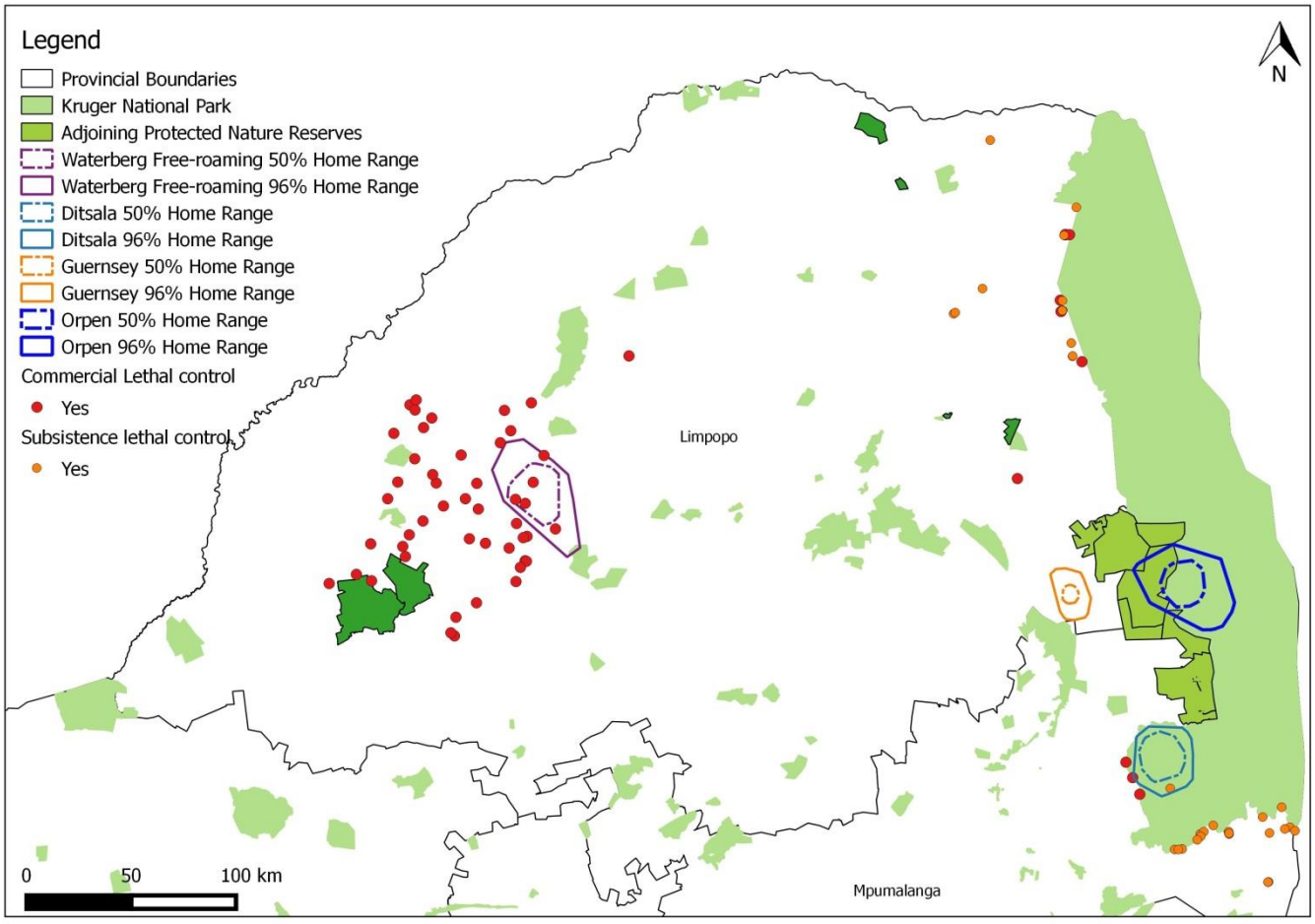


Figure 2. Home (96%) and core (50%) ranges of four collared wild dogs, demarcated by coloured solid-line and dashed-line polygons respectively, in relation to lethal-controlling subsistence farmers (represented by orange circles) and commercial farmers (represented by red circles). A description of each wild dog minimum convex polygon is included in the map legend and index.

The Ditsala pack MCP for 96% home range showed overlap with subsistence and commercial farmers neighbouring the south-western KNP border (Fig. 3). The Waterberg pack MCPs for home and core ranges showed overlap with game and commercial farmers (Fig. 4). No farmers or landowners were surveyed in the Hoedspruit and Orpen areas because of logistical reasons and hence the overlap of farmers' or landowners' attitudes with the Orpen pack MCPs could not be established. The Guernsey and Orpen pack MCPs were, therefore, presented in **Supplementary material:** Figs. S1–S2, and the remainder of the study concentrated on the Waterberg and Ditsala packs.

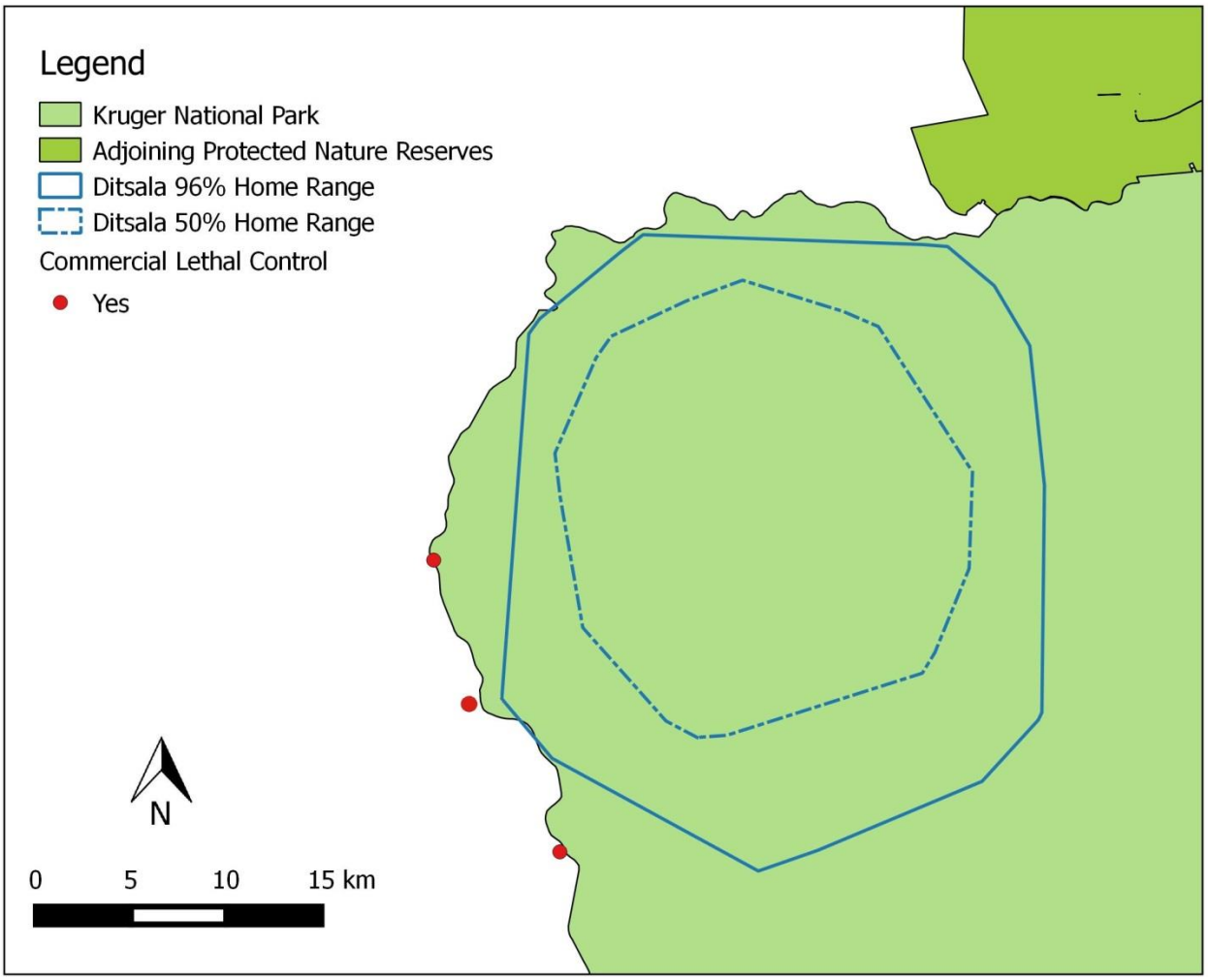


Figure 3. Home (96%) and core (50%) ranges of the Ditsala pack, demarcated by blue solid-line and dashed-line polygons respectively, in relation to lethal-controlling commercial farmers (represented by red circles).

The Ditsala pack MCP for 96% home range showed overlap with farmers that reported using lethal control on the south-western border of the KNP (Fig 3). The MCP indicates that a large portion of the home range perimeter was spent near the fence line.

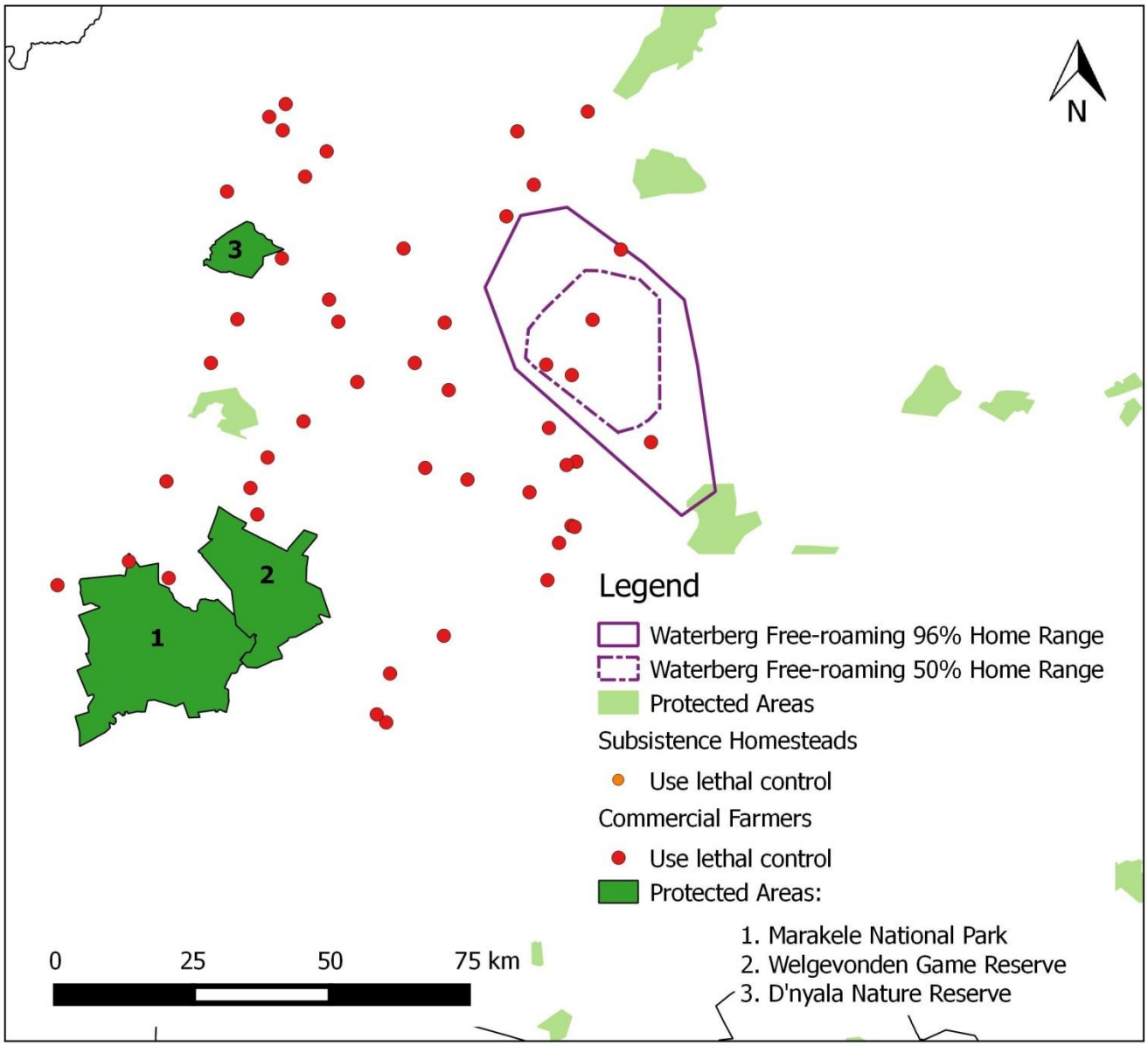


Figure 4. Home (96%) and core (50%) ranges of the Waterberg pack, demarcated by purple solid-line and dashed-line polygons respectively, in relation to lethal-controlling commercial farmers (represented by red circles). Numbers represent key protected areas (Marakele, Welgevonden and D'nyala reserves) in the study area.

The Waterberg pack MCPs for home and core ranges showed overlap with game and commercial farmers (Figs. 1–2) who claimed to implement lethal control (Fig 4). The Waterberg pack 96% MCP of 1 345.39 km^2 was larger than the sum of the neighbouring key nature reserves (Marakele, Welgevonden and D'nyala), with surface areas of 1 132km^2 that do not possess linking corridors between the PAs. The core and home ranges of the Waterberg pack overlap with farmers that reported using poison or shooting carnivores (Chapter 5).

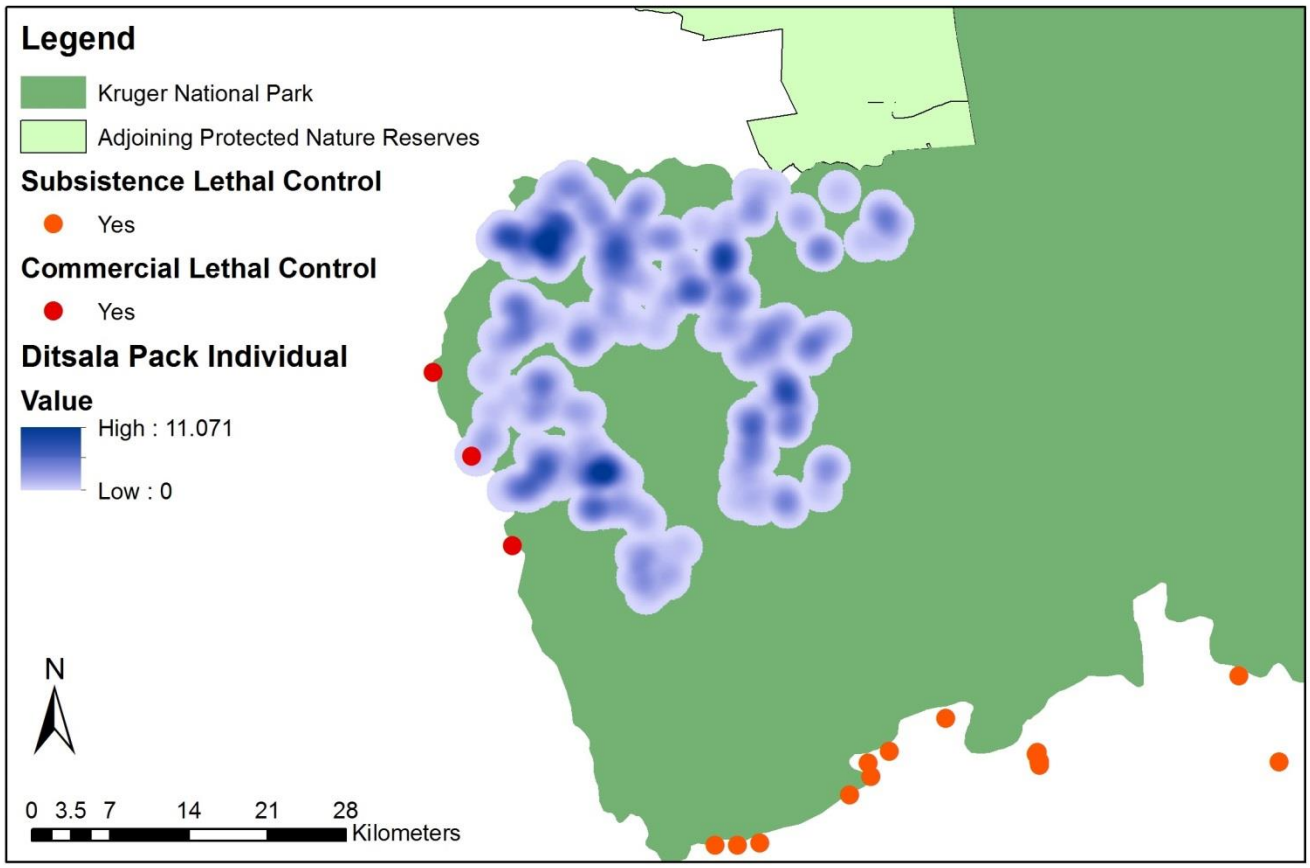


Figure 5. Heat map generated through kernel density estimations for the Ditsala pack, demarcated by blue colour-ramped surface (kernel density estimation), in relation to lethal-controlling subsistence farmers (represented by orange circles) and commercial farmers (represented by red circles). Dark shades of blue represent high densities of global positioning system points.

Ditsala heat maps showed one contact point with farmers that reported using lethal control, which was on the south-western KNP border (Fig. 5). The KDE colour-ramped surfaces showed overlap between pockets of high densities of utilisation and locations of lethal-controlling farmers (Fig. 5). The collared individual spent a large proportion of time near reserve edges, depicted by dark blue shades of clustered GPS points and demonstrated overlap with only one farmer practising lethal control (Fig. 5).

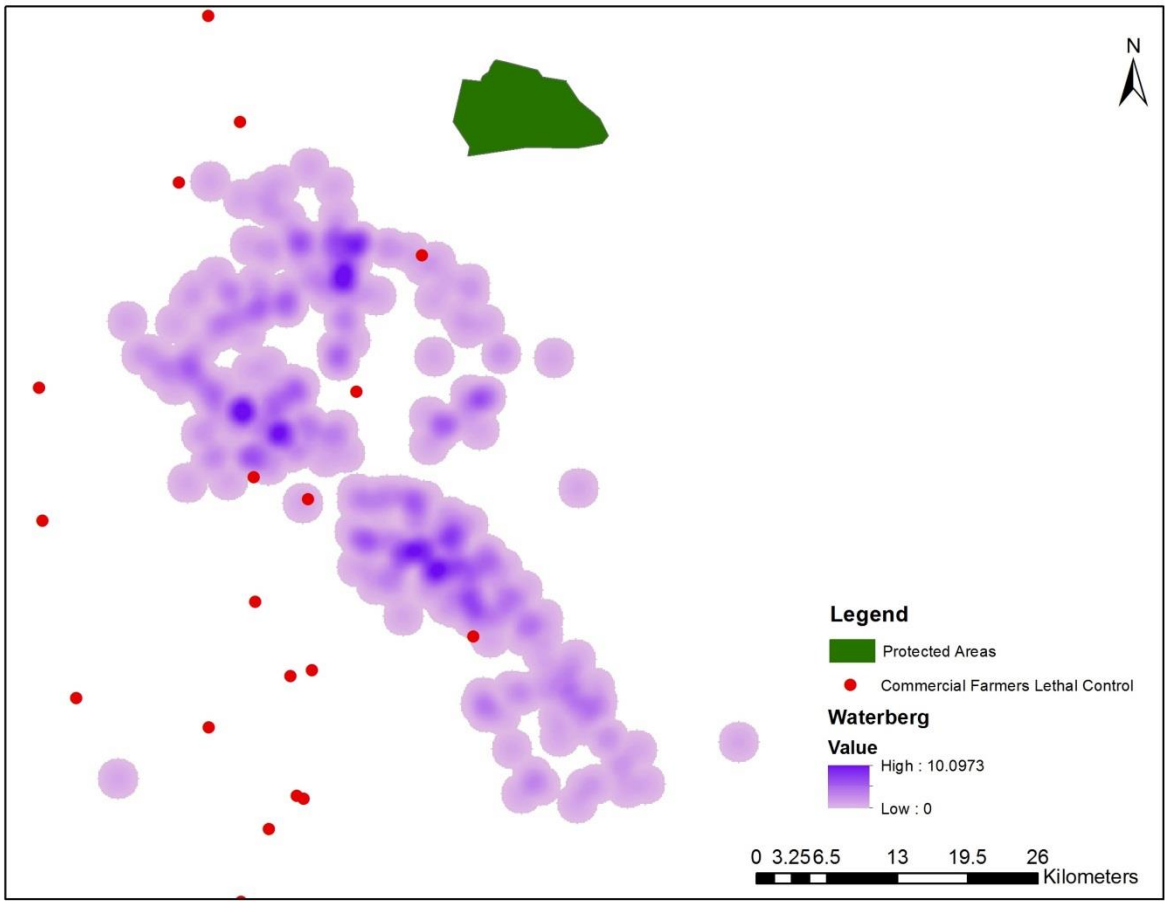


Figure 6. Heat map generated through kernel density estimations for the Waterberg pack, demarcated by purple colour-ramped surface (kernel density estimation) in relation to lethal-controlling commercial farmers (represented by red circles). Dark shades of purple represent high densities of global positioning system points.

The Waterberg pack heat maps showed some overlap with four game farmers that reported using lethal control (Fig. 6). The KDE colour-ramped surfaces showed that the pack largely avoided most lethal-controlling farmers (Fig. 6).

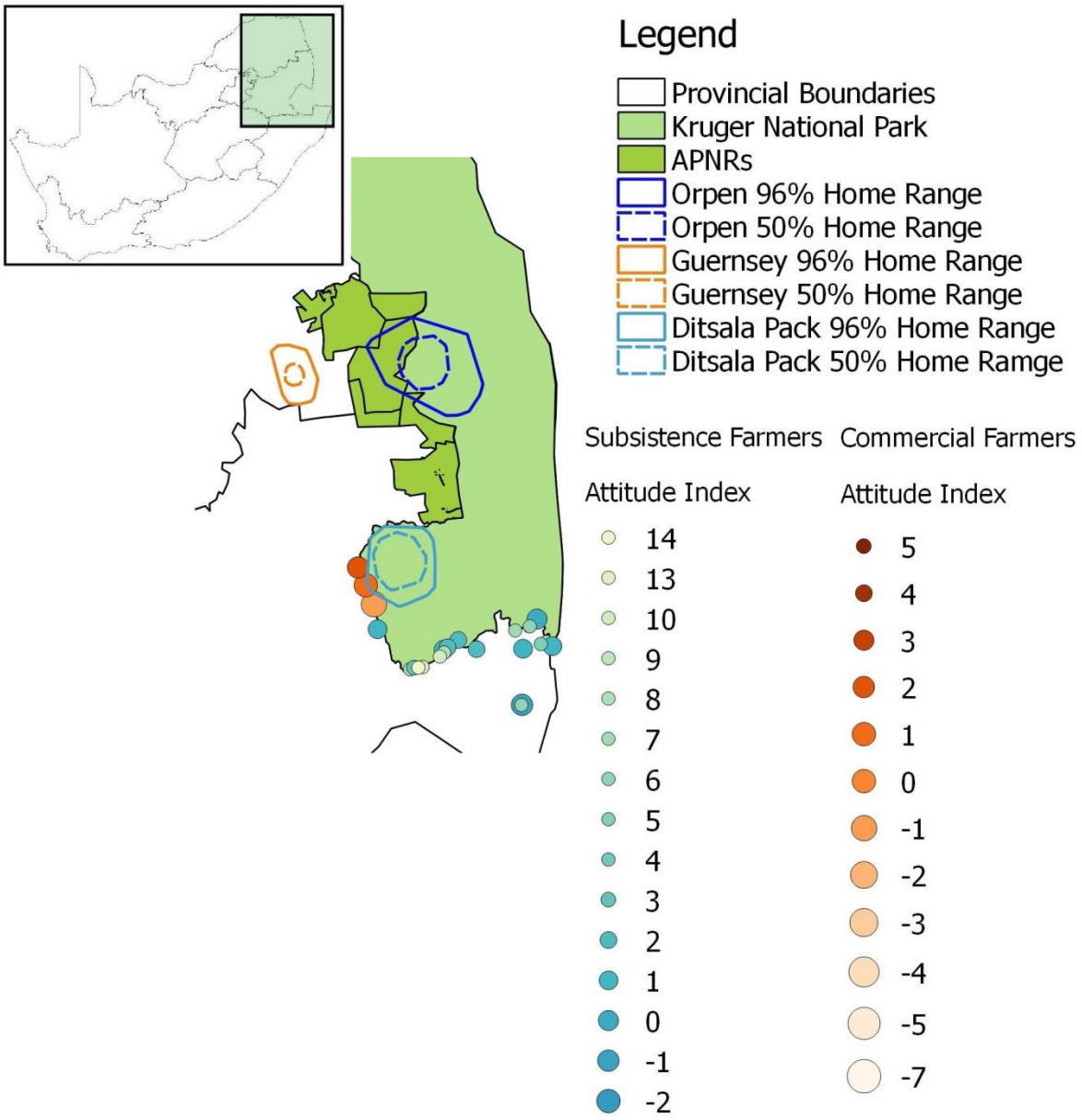


Figure 7. Home (96%) and core (50%) ranges of three Kruger National Park wild dogs, demarcated by coloured solid-line and dashed-line polygons respectively, in relation to subsistence farmer attitude index scores (represented by blue circles) and commercial farmer attitude index scores (represented by orange circles) generated in Chapter 6. A description of each wild dog minimum convex polygon is included in the map legend and index. A map of South Africa is provided in the inset.

The 96% MCP of the Ditsala pack showed overlap with commercial farmers that displayed attitudes index scores in the −1 to +1 range. The Ditsala pack did not exhibit contact with the subsistence farmers that were interviewed (Fig. 7). The Waterberg farmers did not participate in the attitude index score segment of the questionnaire survey.

Discussion

I investigated farmer-wild dog conflict hot spots, using collared wild dogs of 4 packs and farmer questionnaire data, in selected locations of Waterberg and the KNP western border, South Africa. My findings support the prediction that free-ranging wild dogs would experience greater overlap with anthropogenic threats than individuals living within PAs. The free-ranging Waterberg pack displayed the largest home range and, therefore, its home and core ranges, overlapped with farmers that reported shooting and poisoning carnivores, which is consistent with the hypothesis set out by Woodroffe and Ginsberg (1998) that wide-ranging behaviour increases contact with anthropogenic activity.

The Waterberg pack MCP was larger than the sum of the adjacent key nature and game reserves that did not have connecting corridors between the PAs. This scenario represents a dichotomy for wild dogs: If the pack remains free ranging, the individuals would risk poisoning or shooting by farmers, and if they were translocated to a nearby PA, the reserve might not be large enough to meet the habitat requirements of the pack. Mills et al., (1998) indicated that with the exception of the KNP, there are no other PAs in South Africa that are large enough to sustain viable wild dog packs, which seems to resonate the

The Orpen pack had the largest core area and also the largest pack size. The pack also made excursions into the surrounding adjoining protected nature reserves (APNRs) and farmland. Large PAs have been correlated with an abundant natural prey base (Mills et al., 1998) of impala *Aepyceros melampus* and bushbuck *Tragelaphus sylvaticus*, which are preferred prey species of the wild dog (Creel and Creel, 2002) and are abundant in the KNP (Chirima et al., 2012). Consequently, an abundance of wild prey could potentially support a pack with several adults and pups (Mills et al., 1998) and reduce core home range size to areas with high prey densities. Wild dog hunting success has been positively correlated to hunting group size (Creel and Creel, 1995).

The Ditsala pack made excursions close to the KNP south-western boundary, and these movement patterns could reflect the hunting behaviour of the pack. Wild dogs are known to use fences as tools to trap prey by chasing them towards the fences, thus allowing the capture of larger than usual prey (Hofmeyr, 1997). The outcome of these particular hunts could cause damage to fences and increase their permeability (Hofmeyr, 1997). In addition, the 96% home range MCP and KDE heat maps showed overlap with farmers that reported using lethal control on the south-western reserve edge. While I cannot tell the level of overlap spatially and temporally, if wild dogs did utilise farms, they could face potential risk from lethal-controlling

farmers. Similarly, in Kenya, lion *Panthera leo* mortality (due to lethal control) was higher among individuals whose home ranges overlapped with lethal-controlling farmers (Woodroffe and Frank, 2005). A previous study on leopard also showed that individuals that spent more time within their core range suffered lower annual mortality than individuals at the edge of their range (Balme et al., 2010). The MCPs and heat maps indicated that the Ditsala pack spent a large proportion of time at the reserve edges and were potentially vulnerable to persecution (Balme et al., 2010; Woodroffe and Ginsberg, 1998).

In addition to the evidence from the KDE heat maps, the Ditsala pack movements showed overlap with commercial farmers that displayed attitudes index scores in the −1 to +1 range. These commercial farmer attitudes fall within the neutral range since the maximum score could possibly reach a maximum value of +25 or −25 (see Chapter 6). Non-overlap with subsistence farmers supports the idea that subsistence farmers were not affected by carnivore DCAs.

The Waterberg pack KDE colour-ramped surfaces suggested that the collared individual mostly avoided lethal-controlling farmers and spent a large proportion of time between farmland depicted by dark purple shades of clustered GPS points and isolated from farmer GPS points. Similar behaviour has been observed for carnivores that adjust patterns of occupancy in human-dominated landscapes by avoiding high levels of human activity and utilising pockets of dense cover and riparian areas (e.g. lion in Schuette et al., 2013) or dense shrubland (e.g. spotted hyena *Crocuta crocuta* in Boydston et al., 2003). The Waterberg Biosphere reserve is characterised by mountain and sandy bushveld vegetation; Mucina and Rutherford, 2006) with pockets of scrub and woodland (Thorn et al., 2013). It is therefore possible that wild dogs utilised these scrub and woodland areas of the Biosphere network as refugia. It is unlikely that thickets were used to ambush prey because wild dogs prefer long chases to exhaust and hunt prey down (Creel and Creel, 2002).

Conclusions

My study showed that the wild dog packs studied within the KNP remained mostly within the park. Thus, large PAs presented the best scenario for conserving wild dogs due to their abundant natural prey base that can maintain large packs. The two free-roaming packs had contact with anthropogenic activity, but one at least might have avoided contact with people by using refugia. Nonetheless, areas where MCP edges and lethal-controlling farmers intersect

represented potential hot spots for farmer-induced mortality of wild dogs, and consequently wild dog population sinks.

There are some limitations of this study, especially the challenge of predicting the exact movements of a wide-ranging species and to ensure enough respondents are interviewed within that range. It was therefore difficult to find respondents that dwell on farms with identical overlap with the paths of the wild dog home range. A more focused approach can be taken following my study, to interview more farmers that fell within the home-range of the Waterberg pack during future studies. A spatial model in a more focused investigation following my study, could include a land-use layer showing game and livestock density, a habitat-use layer and a layer of conflict drivers such as negative attitudes and lethal control overlaid with wild dog ranges could potentially predict conflict areas.

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Supplementary material

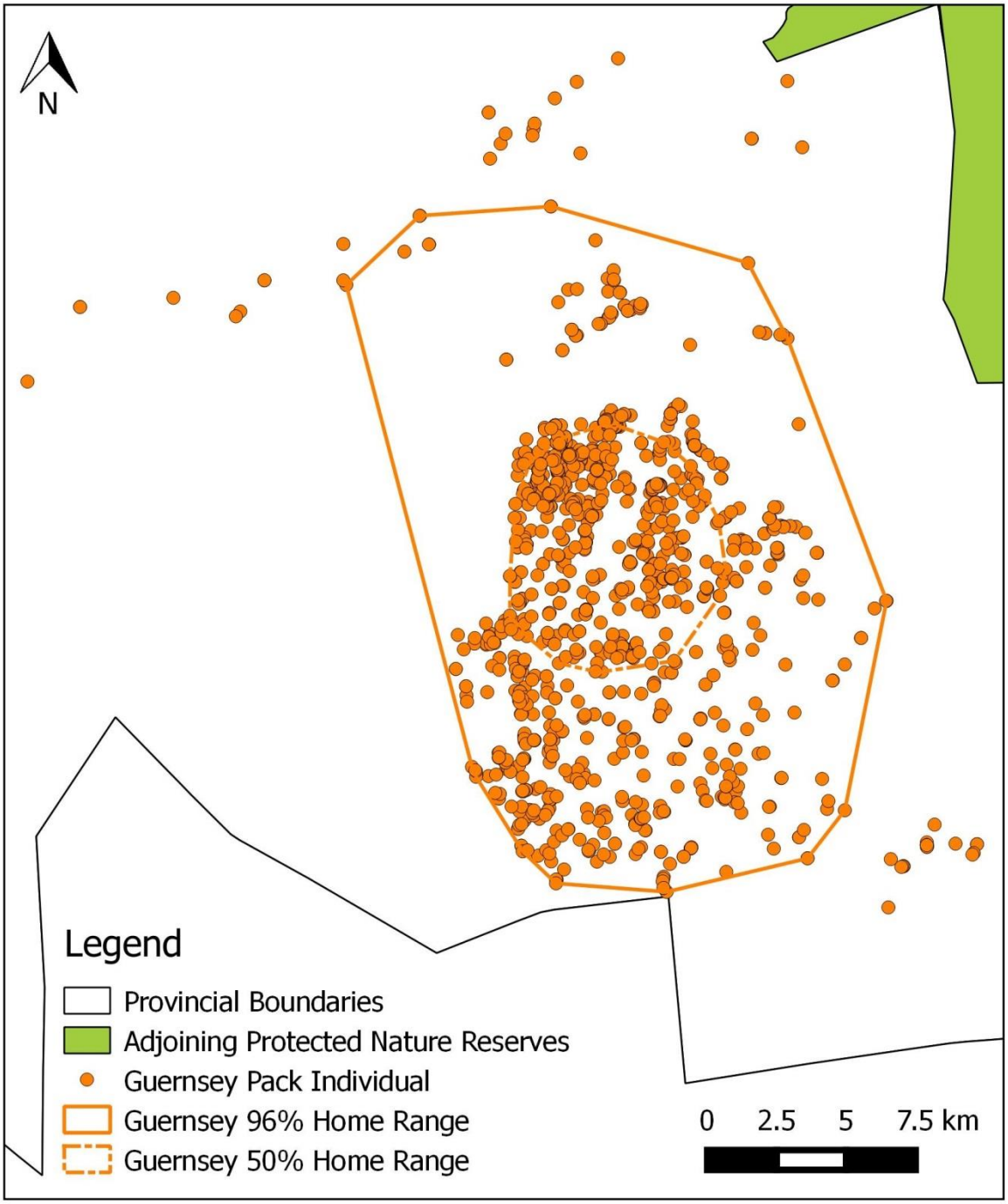


Figure S1. Home (96%) and core (50%) ranges of the Guernsey pack, demarcated by orange solid-line and dashed-line polygons respectively.

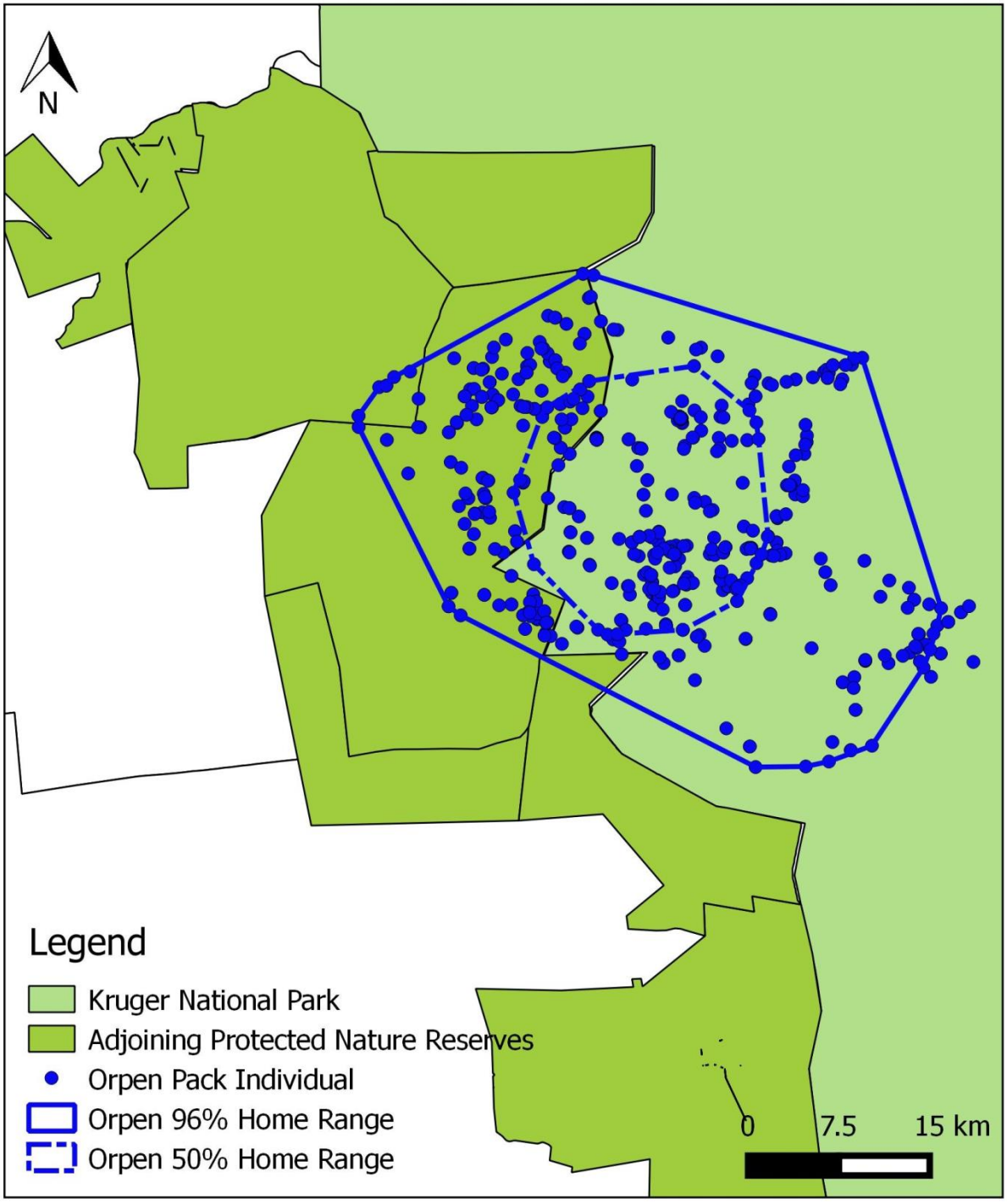


Figure S2. Home (96%) and core (50%) ranges of the Orpen pack, demarcated by blue solid-line and dashed-line polygons respectively.

CHAPTER NINE

General discussion

Human-wildlife conflict (HWC) occurs when the resource requirements of humans and wild animals overlap, leading to competition for food and habitat, tension between people and wildlife, and consequently, strained relations between people and conservation authorities (Gilbert and Dodds, 2001; Woodroffe et al., 2005). People often respond to wildlife depredation with preventative and/or deliberate lethal control that sometimes affects species that are vulnerable to extinction (Anthony, 2007). Furthermore, there is anecdotal evidence that HWC may be a serious threat to subsistence farmers in comparison with commercial farmers, but no comparative studies have been made to date.

I investigated how subsistence and commercial farmers located on the edges of protected areas (PAs) in north-eastern South Africa were affected by and responded to problem animals. I used a combination of methods to obtain information regarding the demographic and physical attributes of subsistence households and commercial farms that were important predictors of the scale of HWC. These approaches included classical, semi-structured questionnaire interviews, inspections of farms/gardens to verify farm attributes and satellite or radio-collared African wild dog (hereafter wild dog) *Lycaon pictus* individuals.

In this concluding chapter, I discuss the important findings of my research and compare results from my investigations with other available studies on HWC. My experimental design was unique, examining the dichotomy of third- and first-world economies (Armstrong et al., 2008) represented by subsistence and commercial farmers respectively who operated concurrently in north-eastern South Africa amidst one of the highest levels of biodiversity in the world. My research investigations were novel and revealed several parameters that determine how HWC affects biodiversity as well as the livelihoods of subsistence and commercial farmers in South Africa, with broader implications for HWC worldwide. Finally, I identify deficiencies in the associated scientific literature and suggest future research avenues.

Key findings of the study

Prior to addressing the aims of my study, I conducted a meta-analysis of the occurrence of HWC globally, which revealed that people from developing countries were notably affected

by a higher diversity of damage-causing animals (DCAs) compared with developed countries (Chapter 2). Moreover, local communities contiguous with protected natural areas were most affected (49 different wildlife species globally), followed by subsistence farmers and then commercial farmers. Furthermore, local communities and commercial farmers jointly experienced the highest number of HWC incidences compared with subsistence farmers. Remarkably, commercial farmers occupied a more prominent conflict profile (i.e. high vulnerability of such people and farming commodities to human-wildlife conflict, due to a relatively high number of HWC cases reported in the published literature for such groups, in combination with a relatively high number of moderate to high-scale conflict species that commonly affect such groups of people) in the literature, greater than that of the presumably vulnerable subsistence farmers, perhaps because of the greater research attention on commercial farmers. Generally, carnivores and primates appeared prominently in the literature review, depredating a wide range of agri-pastoral commodities globally. The findings of the meta-analysis review shaped and developed the aims and objectives for the rest of my study.

The initial aim of my study was to examine how subsistence and commercial farmers that ranched or cultivated in the same geographic area were affected by and responded to problem animals in selected localities of north-eastern South Africa (Chapter 4). Predictably, subsistence farmers suffered a greater number of crop-depredation incidences than commercial farmers. Importantly, I further identified a specific set of predictors that exacerbated HWC, including large households (≥7 occupants per household), environmental-related challenges (e.g. insect pests, soil erosion and theft) and the lack of electrified fencing.

In a subsequent set of investigations, I identified the leading DCAs associated with the greatest number of depredation incidences and determined whether or not these DCAs were common to subsistence and commercial farmers (Chapter 5). My results demonstrated that subsistence farmers lost a significantly greater number of crop species to depredation than commercial farmers, with a subsistence community at Ndumo in KwaZulu-Natal Province, experiencing the highest numbers of crop species lost. Moreover, maize *Zea mays*, produced by both subsistence and commercial farmers, was the most frequently raided crop. It is also noteworthy that primates were reportedly responsible for the highest number of crop-raiding incidences, particularly on subsistence farms. Furthermore, poultry and young livestock (calves/lambs/kids/foals) were most often depredated throughout the study sites. Commercial livestock farmers reportedly experienced greater financial loss due to depredation than did subsistence livestock farmers. Interestingly, joint leading livestock depredators were the caracal *Caracal caracal*, wild dog and leopard *Panthera pardus*. Moreover, the chacma baboon *Papio*

ursinus and vervet monkey *Chlorocebus pygerythrus* were reportedly responsible for the highest number of crop-raiding incidences, particularly on subsistence farmland. My findings also support the prediction that commercial farmers would comprise a significantly higher number of respondents who practised retaliation compared with subsistence farmers, manifested as shooting and poisoning of wildlife. Importantly, my results indicated that commercial farmers most frequently persecuted carnivores, while subsistence farmers exclusively persecuted primates.

Subsequent to the findings that subsistence and commercial farmers persecuted DCAs (Chapter 5), I further gauged the attitudes and opinions of subsistence and commercial farmers to wildlife and conservation issues (Chapter 6) using the semi-structured questionnaire interviews and a geographic information system (GIS) attitude index (a method to visualise the spatial distribution of subsistence and commercial farmers' attitudes). Results indicated that subsistence and commercial farmers hold positive and negative attitudes towards wildlife for different reasons. No differences were found in the attitudes between subsistence and commercial farmers, with the exception that subsistence farmers demonstrated a significantly higher percentage of agreement with the statement, 'Wildlife should be kept only in fenced-off areas'. Collectively, positive attitudes accounted for seven of the 13 statements relating to ecocentric attributes (concern for the ecosystem), such as environmental education, tourism and a willingness to learn about non-harmful DCA control. Overall, farmers were negative towards six of the 13 statements, showing a low tolerance for crop and livestock depredation. Approximately 38% of respondents indicated that they elicited help with DCA-related issues, citing the need for conservation authorities to assist with "better fencing", "better compensation" and "more communication". Interestingly, both high negative and high positive GIS scores coincided in the same geographic areas of Giyani and Ndumo, rural areas of the Limpopo and KwaZulu-Natal provinces for both subsistence and commercial farmers. Hence, a specific set of variables and typologies predicted the attitudes and opinions of farmers towards wildlife. Positive attitudes related to employment prospects, tourism revenue and the potential for mentorship through environmental education. Negative attitudes and opinions related to free-ranging and stray wildlife (individuals that transgress PA boundaries), the negative potential of wild animals to damage farmed resources and the lack of communication with conservation authorities.

I subsequently assessed the attitudes and opinions of conservation practitioners to people and local communities (Chapter 7) using the same methodology adopted for Chapter 6. In general, positive responses dominated over negative responses towards wildlife and local human

communities, while no significant differences in attitudes or opinions between practitioners located in all provinces were observed. Positive responses towards wildlife were associated with the ecocentric, aesthetic and economic values of wildlife, while positive responses towards local human communities related to community-conservation oriented values. Importantly, negative responses towards local human communities pertained to a disinterest and indifference towards the socio-economic needs of local people, in addition to protectionist ideologies, that ecosystems can only persist devoid of anthropogenic disturbance or influence. Moreover, conservation practitioners revealed predictably negative opinions towards poaching, showing low tolerance to factors that threaten wildlife persistence. Notably, the cumulative mean GIS attitude indices (n = 49) for wildlife and local human communities were +3.98 and +2.31 respectively. In all provinces sampled, most conservation practitioners indicated that they implemented trans-boundary monitoring, environmental-education and community-engagement programmes. Hence, conservation practitioners overall held mean positive values towards wildlife and local human communities, suggesting that a shift from protectionist ideologies to community conservation is likely in north-eastern South Africa.

Finally, I examined the movement patterns of four satellite-tracked or radio-collared wild dog individuals from different packs in selected localities of Waterberg and the south-western border of the Kruger National Park (KNP), South Africa, which are areas where they are lethally persecuted (Chapter 8). During this investigation, I used minimum convex polygons (MCPs) and heat maps (kernel density estimations: KDEs), characterised by dense clustering of wild dog global positioning system (GPS) points to assess whether or not wild-dog core areas of utilisation overlapped with lethal-controlling farmers. The free-ranging Waterberg (Limpopo Province) pack displayed the largest home range (1 345 km^2), followed by the packs within the KNP (797 km^2; Orpen: 363 km^2) and then the free-roaming Guernsey pack (352 km^2) along the KNP western border. Minimum convex polygons of the Ditsala and Waterberg packs overlapped with farmers that, during questionnaire interviews, reported the use of lethal control. I considered areas where MCP edges and lethal-controlling farmers intersected as potential hot spots (areas where wild-dog home ranges exposed them to anthropogenic threats). Such threats included farmers who practised lethal control of free-roaming and stray wildlife and the potential farmer-induced mortality of wild dogs. Areas where farms overlapped with MCPs on PA edges represented wild dog population sinks (features within a habitat or home range that may affect the population growth or decay/decline).

Interestingly, KDEs of the Ditsala pack demonstrated that the pack spent a large proportion of time near reserve edges, depicted by overlap between clustered wild-dog and

farmer GPS points. In addition, KDEs of the Waterberg pack indicated that the pack avoided farmers, utilising pockets of scrub and woodland areas of the Waterberg as refugia.

Implications and contributions of my findings

Global meta-analysis of human-wildlife conflict

The meta-analysis review ranked South Africa as having one of the highest numbers of HWC cases in the world caused by a distinct group of carnivores, primates and mega-herbivores. Hence, results of the review imply that the dichotomy between first-world and third-world economies exemplified in South Africa provides a model of global patterns in HWC. The review also bore implications for developing countries, typified by marginal farming operations that are vulnerable to environmental factors (UNDP, 2008). The effects of HWC, therefore, would have potential consequences extending to poor nutrition in such countries (FAO, 2015; Hill, 2000; World Bank, 2013). A substantial increase in publications of HWC in Africa and Asia in the last 16 years demonstrated emergent geographic patterns of HWC that correspond to increasing efforts by conservation authorities to address HWC (Madden, 2004). Moreover, my review reaffirmed the position of local and subsistence communities as a particularly susceptible guild to HWC (Infield and Namara, 2001), an issue that undermines household food security (Hill, 2000; Infield and Namara, 2001). The meta-analysis review also suggested that primates and carnivores were high-impact conflict species appearing prominently in scientific papers. There were several examples in the literature in which primates and carnivores are often persecuted (Inskip and Zimmermann, 2009; Macdonald et al., 2012; Treves and Karanth, 2003; Woodroffe and Frank, 2005), demonstrating that the threats facing felids, canids and primates were often the same and occur in the same region (Macdonald et al., 2012).

Subsistence versus commercial farmers

Preceding and existing studies on HWC have examined the impact of problem animals on subsistence and commercial farmers separately. Yet DCAs together with several environmental impediments, such as climate change (Gan et al., 2015), indigenous habitat fragmentation and agricultural expansions (FAO, 2015), affect both subsistence and commercial farmers. The results of my study bear numerous important ramifications for subsistence and commercial farmers.

The empirical findings of my research established subsistence farmers to be more vulnerable to wildlife crop depredations compared with commercial farmers. My study contributed the first comparative assessment of how subsistence and commercial farmers were affected by crop raiders, both globally and in South Africa. My findings regarding HWC in north-eastern South Africa were consistent with the plight of other African countries (Fungo et al., 2013; Infield and Namara, 2001; Sillero-Zubiri and Switzer, 2001) such as Uganda, Ethiopia and Tanzania where crop-raiding occurs frequently with significant damage to crops (Fungo et al., 2013). The suggestion that crop-depredation could potentially compromise household food production and nutrition were consistent with my meta-analysis review (Chapter 2), together with several other studies (FAO, 2015; Hill, 2000; World Bank, 2013).

The area that experienced the highest numbers of crop species lost was predominantly rural, namely Ndumo, and is of particular concern because this community houses some of the poorest households in KwaZulu-Natal, South Africa (Statistics South Africa, 2007). I also found that maize, a staple food crop cultivated on both subsistence and commercial farms, was most often raided and hence, food security of such subsistence and commercial farms could be compromised (Weladji and Tchamba, 2003). Furthermore, about three million rural subsistence households in South Africa are affected by drought (Department of Agriculture Forestry and Fisheries, 2010), which exaggerates the effects of wildlife depredations on crops and livestock. As a result, tensions between farmers and conservation authorities can intensify when crops that survive drought (Tweheyo et al., 2005) become vulnerable to depredation.

I also demonstrated that the proportion of livestock farms affected by depredation in South Africa was the same for subsistence and commercial farmers. However, rural areas of Giyani and Ndumo, in Limpopo and KwaZulu-Natal Provinces respectively, experienced the highest losses of livestock/poultry to wildlife depredations when compared with other areas. General environmental conditions prevalent in South Africa, such as heat stress and low rainfall (Thorn et al., 2012), could compound the effects of HWC for landowners within these areas, some of whom earn marginal incomes (Statistics South Africa, 2007). Hence, livestock farmers must overcome environmental challenges and their repercussions on grazing conditions (Chapter 4), in addition to frequent depredation of poultry and livestock in these areas.

Importantly, poultry and young livestock, which are important staple food security commodities (FAO, 2015), were most frequently lost to wildlife depredation, specifically in subsistence homesteads (Chapter 5). According to the FAO (2015), poultry and egg production has increased in importance as a human food product as opposed to ruminants, especially in developing countries. Moreover, the loss of young livestock due to predators can compromise

future animal production for subsistence farmers (FAO, 2015). Furthermore, the farmer reports gathered during the present study regarding poultry and livestock depredations were consistent with several other studies in developing countries in that carnivores were responsible for most of the young and small-bodied livestock mortalities through depredation (Avenant and Du Plessis, 2008; Sangay and Vernes, 2008; Van Niekerk, 2010). Therefore, considering the sum of adverse climatic conditions (Gachene et al., 2015; Gan et al., 2015), prominent poverty levels (Hill, 2000) and wildlife depredations of important food products in developing countries (Sangay and Vernes, 2008), I suggest that HWC may compromise food security for subsistence farmers in South Africa.

The current study demonstrates that commercial livestock farmers in north-eastern South Africa experienced greater financial loss due to depredation than subsistence livestock farmers, particularly regarding young livestock (calves/lambs/kids/foals). These results were consistent with the findings of Van Niekerk (2010) who demonstrated that in pastoral areas of five South African provinces, the black-backed jackal *Canis mesomelas* and the caracal *Caracal caracal* were associated with the depredation of young livestock and older small livestock (Van Niekerk, 2010). Livestock damages for both subsistence and commercial farmers collectively amounted to R4 373 063 (US$275 200 at a rand-dollar exchange rate of 1US$=R15.88) from 2013 to 2014. These estimations were based on the replacement value (market price) of each livestock individual lost per species and does not consider sale or auction prices. Moreover, Van Niekerk (2010) estimated the annual cost of depredation to the game and commercial livestock industry to be extensive (approximately R 1.4 billion collectively for the five provinces). Hence, the perceived losses due to carnivore depredation in South Africa were great. I speculated that the collective losses of game species were greater because the unit prices of game species are exorbitant and regulated by the Game Ranchers' Association and Livestock Trader organisation. My assumption is in line with several other studies (Thorn et al., 2015; Treves and Karanth, 2003; Van Niekerk, 2010; Woodroffe et al., 2005) that report significant monetary losses for the commercial livestock industry due to depredation. However, the financial losses incurred by commercial farmers in South Africa are still debatable (McManus et al., 2014). While some studies (Treves and Karanth, 2003; Van Niekerk, 2010; Woodroffe et al., 2005) demonstrated that livestock depredation can potentially jeopardise commercial farming livelihoods, others showed negligible losses to commercial game and livestock holdings (McManus et al., 2014; Thorn et al., 2012). I speculated that financial losses for subsistence farmers were uncertain when compared with commercial farmers since the currencies of losses due to depredation were unique for subsistence households. Subsistence households are not involved in sale or barter,

instead, losses translate into impacts on their livelihoods (Kates and Dasgupta, 2007). In addition, livestock holdings are a source of social standing and assets to rural households (especially to Zulu, Swazi, Xhosa and northern and southern Ndebele cultures) (Herbst and du Plessis, 2008). Lobola or bride price (dowry) for example, was historically paid with cattle, and although some transition of cash dowries has occurred, some rural people still practice the tradition of offering cattle, or even a combination of money and cattle (Herbst and du Plessis, 2008). Hence, livestock depredation will have social and economic costs on subsistence farmers that cannot be weighted in monetary terms, but nevertheless translate into significant impacts on the social status and livelihoods of rural people.

Damage-causing animals and retaliatory or preventative killing of wildlife

Wildlife populations in Sub-Saharan Africa face the same environmental and climatic crises as humans, including drought and associated poor veld conditions (Gaughan et al., 2015; Loveridge et al., 2006; Thorn et al., 2012). These adverse environmental factors are diminishing wildlife populations substantially, which have the additional threat of lethal persecutions by farmers (Hazzah et al., 2009; IUCN, 2012). My research demonstrated the first direct comparison of how subsistence and commercial farmers respond to DCAs. I also presented new information regarding the wild animals responsible for crop and livestock depredation and the types of persecution they face by farmers in north-eastern South Africa.

Several scholars attribute the success of certain high-impact DCAs to their biological characteristics and ability to survive opportunistically in human-dominated environments, particularly farmland (Else, 1991; Marker and Dickman, 2005; Di Minin et al., 2016; Nowell and Jackson, 1996; Sillero-Zubiri and Switzer, 2001). Important conflict species identified in the present study, namely the chacma baboon, vervet monkey and leopard showed such adaptability to anthropogenic settings. Several authorities postulated that primates and felids were likely to subsist along PA edges of indigenous habitats and farmland. Here, primates and leopards could utilise the protection or refuge and the natural resources provided by the PAs in addition to the crops or livestock of farms contiguous with such PAs (Naughton-Treves, 1998; Schiess-Meier et al., 2007; Sillero-Zubiri and Switzer, 2001). The farms surveyed during my study were contiguous with PAs, making the inference that damage-causing primates and felids displayed habitat adaptive plasticity (PAs and farmland) plausible.

Several studies suggest that the advantages associated with depredation outweigh the costs for DCAs (Avenant and Nel, 2002; Kamler et al., 2012; Kaplan et al., 2011; Warren et al., 2011). In Nigeria, for example, the olive baboon *Papio anubis* gains energy and enhances

reproductive benefits through crop-raiding (Warren et al., 2011). Although farmers implement preventative and retaliatory practices against raiders, the benefits of crop-raiding (better nutrition from high-quality cultigens, a decrease in pathogens and subsequent enhanced reproduction and offspring survival) outweigh the costs (farmer retaliation; Warren et al., 2011). Similarly, the nutritional benefits of livestock raiding (a constant and concentrated food source) outweigh the risks (Avenant and Du Plessis, 2008; Avenant and Nel, 2002; Kamler et al., 2012). For example, South African studies suggest that the black-backed jackal and the caracal may select livestock opportunistically or during periods of high metabolic activity such as pregnancy and lactation (Avenant and Du Plessis, 2008; Avenant and Nel, 2002; Kamler et al., 2012). Hence, farming commodities are generally nutritionally denser than natural food (Avenant and Du Plessis, 2008; Warren et al., 2011), thus significantly increasing incentives to depredate.

I confirmed that although both subsistence and commercial farmers practised lethal control, commercial farmers comprised a significantly greater number of respondents who practised shooting and poisoning of carnivores. Importantly, mine is the first study to establish how people from different economic classes managed problem animals (Chapter 5). Results concerning commercial-farmer retaliatory behaviour were consistent with other studies in that commercial cattle farmers in South Africa and Zimbabwe were generally antagonistic towards large carnivores (Lindsey et al., 2005). These farmers were motivated by the monetary worth of their game and farming commodities (Marker and Schumann, 1998), with low tolerance towards wildlife (Schumann et al., 2008). Repercussions of carnivore persecutions have particularly important consequences for the survival of endangered canids (Woodroffe et al., 2005) and felids (Swanepoel et al., 2014) that are in some cases are free roaming and frequently occupy human-dominated areas such as farmland in South Africa (Mills and Gorman, 1997). I tested this assumption in a case study of the movement patterns of collared wild dogs (Chapter 8), where the home range of free-ranging wild dogs intersected with farmers who practised lethal control. I concluded that such wide-ranging and free-ranging species were inevitably vulnerable to persecution by farmers, although the Waterberg pack demonstrated avoidance of most lethal-controlling farmers by using vegetation thickets.

Nine different types of retaliatory practices towards wildlife were reported by subsistence and commercial farmers, namely beating with sticks and stones, hitting with sticks, mobbing and attacking with spears, poisoning, shooting, snaring, spearing, throwing rocks and trapping. I found that subsistence farmers focused retaliatory behaviour mainly towards primates. This may be a direct consequence of their principal land-use practice, namely crop farming, which could entice primates. Retaliatory behaviour by subsistence farmers could be a preventative measure to

protect their crops from raiders rather than persecutory action, with several socio-economic elements driving subsistence-farmer reactions to wildlife. These findings (Chapter 5) were consistent with those of Chapter 4, in that in the face of poverty, adverse climatic conditions (Thorn et al., 2012) and resource damages due to wildlife depredation, HWC threatens food security and livelihoods and more so for subsistence households in South Africa.

Attitudes and perceptions

While the attitudes of commercial farmers and local people towards wildlife have been documented independently and extensively (Anthony, 2007; Jackson and Wangchuck, 2001; Lindsey et al., 2005; Mishra et al., 2003), my study was the first direct comparison of attitudes towards wildlife and conservation issues by concurrently operating subsistence and commercial farmers (Chapter 6). I found that subsistence and commercial farmers produced hostile and negative attitudes towards wildlife that threatened their crops and livestock specifically, with subsistence farmers expressing attitudes that were more negative. These attitudes may be motivated by both the perceived nutritional impacts on their households and economic threats to their livelihoods. Other studies have also correlated negative attitudes to perceived economic threats from wildlife (Anthony, 2007; Davies and Du Toit, 2004). In my study, only one third of respondents indicated that they elicited help from conservation authorities with depredators. These findings have particularly negative implications for wildlife conservation since previous studies showed that lack of communication with conservation authorities increased intolerance of wildlife (Anthony, 2007; Madden, 2004). Furthermore, retaliatory killing of wildlife increased when communication between neighbouring communities and PA authorities weakened (Jackson and Wangchuck, 2001; Madden, 2004). Since subsistence and commercial farmers produced a mix of negative and positive responses to wildlife, there is some potential for HWC mitigation. However, some scholars question whether or not positive and negative attitudes could manifest into changed behaviour towards wildlife and conservation issues (Attwell and Cotterill, 2000; Manfredo et al., 2004).

Persecution of wildlife globally is underpinned by negative attitudes and negative perceptions of people towards perceived DCAs (Anthony, 2007), hence, such assessments should become an essential aspect of future PA management policies. Mine is one of few studies examining the attitudes and opinions of conservation authorities towards local communities living adjacent to PAs. Importantly, the design of my study was unique (Chapter 7) in that it compared the values that conservation practitioners held towards wildlife and people to assess whether the values and standards towards wildlife surpassed the values and considerations

towards local people and communities. Another study focussing on the attitudes and opinions of conservation practitioners towards local people who resided and worked near or within a protected area in Uganda (Archabald and Naughton-Treves, 2001), reported that sharing tourism revenue with local communities improved community attitudes towards PAs and wildlife (Archabald and Naughton-Treves, 2001).

I revealed that the positive attitudes of both subsistence and commercial farmers at all study sites were associated with factors that potentially generated employment and income (tourism) or enhanced knowledge and skills (environmental education and non-harmful, wildlife deterrents). Such positive correlates have been demonstrated in other studies, particularly with employment creation around the KNP (Anthony, 2007) and income generation in KwaZulu-Natal, South Africa and Tanzania (Infield, 1988; Newmark et al., 1993). Moreover, environmental education may also assist in decreasing myths and misconceptions regarding wildlife, especially for species that have gained a notorious reputation for depredation without evidence (Lindsey et al., 2005).

The predominantly positive attitudes towards local human communities and wildlife alike by conservation practitioners indicates a transition from colonial, protectionist PA management regimes to community conservation. It is noteworthy that negative responses towards local human communities pertained to a disinterest and indifference towards the socio-economic needs of local human communities, in addition to protectionist ideologies (i.e. wildlife can only survive in isolation from anthropogenic disturbance). It is likely that uncontrolled harvesting of biological resources, for example, is still a concern for conservation authorities. Furthermore, conservation practitioners considered poachers to be criminals, showing intolerance to factors that threaten biodiversity, especially to species that occur at low densities (Kennedy et al., 1994).

Many conservation practitioners gave positive feedback towards the idea of community-based-natural-resource management (CBNRM), indicating people-orientated conservation is likely. For South Africa, in particular, a shift from pre-colonial biodiversity preservation (DeGeorges and Reilly, 2008) to community conservation (Cock and Fig, 2000; Maddox, 2002) has the potential to alleviate HWC and reconcile the historical exclusion of local human communities from wildlife management and sustainable resource use. In addition, CBNRM also bears advantages for both communities and conservation authorities. Local human communities could serve as guardians over biodiversity and acquire knowledge around contemporary conservation methods and sustainable farming techniques through environmental education

(Zhang and Wang, 2003). Hence, through CBNRM, local communities could work to protect wildlife outside PAs, as seen in Zimbabwe (Child, 1995).

Future research avenues in human-wildlife conflict

The different sample sizes for subsistence and commercial farmers were a methodological limitation of the present study, where the number of subsistence farmers sampled, outweighed the number of commercial farmers. This was attributable to the number of farmers of each type present (factored against the scale of farming) and the number of willing participants in the study. Future studies should attempt to collect data from adequate and relatively equal samples of subsistence and commercial farmers, if possible. A more focused study in the Waterberg will also elucidate some of the emerging trends of lethal control, by examining subsistence and commercial farmers who operate concurrently with multi-crop commodities (De Klerk, 2003). This will elucidate whether wildlife other than carnivores, such as primates and rodents, have engendered lethal persecution in this area.

Future studies should consider several questions that emerged from the current study. Studies in other parts of the country are required with different environmental conditions and farming practices (e.g. monoculture sugar cane *Saccharum* spp. and vineyards) to elucidate whether or not my findings were generalisable across South Africa. In addition, direct observations of DCAs would be worthwhile and would confirm perceived threats with evidence. Such studies should also complement direct observations with the use of camera traps, for example, to document cryptic and elusive species, such as the leopard, which has often gained a notorious reputation for depredation but without evidence.

In addition, significant differences between study localities emerged after analysis, and therefore how the characteristics and distance of PAs from farms sampled influences HWC is an issue that a more focused future study can address. Proximity of PAs from farms could also influence opportunistic feeding of species that show high adaptability to anthropogenic settings (Marker and Dickman, 2005; Di Minin et al., 2016; Nowell and Jackson, 1996; Sillero-Zubiri and Switzer, 2001). Since the findings of my study showed that one pack of free-ranging wild dogs reduced risk encounters with farmers by retreating into herbaceous thickets, this endangered species could serve as an important case study to further assess habitat adaptive plasticity to contiguous and distant farmland, even in combination with other adaptable species

such as chacma baboon and leopard (Schiess-Meier et al., 2007; Sillero-Zubiri and Switzer, 2001).

The magnitude of crop raiding is still poorly understood. Although I identified crop-raiders and the crop species damaged through HWC, I could not quantify crop losses precisely in the present study. Economic and caloric losses were also not measured due to limitations of the questionnaire survey, which received vague and incomplete responses regarding the quantity of crops lost to depredation. I suggest that prospective studies incorporate a mixture of complementary analytical methods to measure crop damage and the associated costs, as well as the effect of crop diversity on the probability of experiencing HWC. Such methods would be critical to evaluate the impact of HWC on food security and nutrition, particularly in developing countries where crops form a large part of the diet of rural communities (Hill, 2000).

Environmental factors intensify depredations of farming commodities from wealthy and poor populace, posing serious threats to people and food security at household and commercial levels (FAO, 2015). Unfortunately, the latest El Niño phenomenon did not coincide with my field data collection through surveys, and I could not test the effects of this weather occurrence on HWC in South Africa. However, El Niño will have had an important impact on HWC in South Africa. El Niño is a sporadically occurring, complex series of climatic events associated with below-normal rainfall in southern Africa (Gan et al., 2015). The combination of El Niño and the general water scarcity in southern Africa (Thorn et al., 2012) constrained the supply of rain-dependent maize by 30% in 2015 (Gachene et al., 2015) and significantly diminished agricultural output at household and commercial levels with associated elevations in food-prices and inflation in general (Gachene et al., 2015). It is likely that such reduced crop production for subsistence and commercial farmers would affect and possibly decrease tolerance of wild animals on farmland from 2015 to 2017 while farmers recover from diminished crop production, and this warrants further investigation.

Systematic and in-depth comparative studies of subsistence and commercial farmers are required in other countries worldwide, especially in those where first- and third-world economies function concurrently. Such studies would elucidate whether or not the trends and patterns of HWC presented in my study are exemplified worldwide. Such prospective studies should also identify the important depredators associated with the greatest levels of damage in these countries to clarify if such species demonstrate habitat plasticity on the edges of farms and PAs. Importantly, whether or not these species are common to subsistence and commercial

farmers should be elucidated. In addition, it would be worthwhile to investigate the retaliatory and non-lethal control practices implemented by such farmers to mitigate depredation.

Conclusions

I examined how subsistence and commercial farmers that neighboured PAs in north-eastern South Africa were affected by and responded to problem animals. My study was unique and the first to investigate the dichotomy of the poor and wealthy people, represented by subsistence and commercial farmers respectively, who operated side by side amidst dense wildlife populations. I found several variables that determined how HWC affected carnivores and primates as well as the livelihoods of farmers in South Africa. Subsistence farmers and commercial farmers were equally affected by HWC, but differed in the types of crops and livestock/poultry/game depredated. While commercial farmers may be able to deter wildlife through the use of fencing and lethal control, subsistence farmers do not have the resources for such deterrents. Instead, they employ other, often passive, forms of wildlife control. Nonetheless, the loss of food production concomitant with other environmental drivers will exacerbate their plight, leading to food insecurity. Specifically, I found that primates and carnivores frequently depredated staple food security crops, poultry and young livestock. Of particular concern to conservation authorities is that two leading damage-causing carnivores, namely wild dog and leopard *Panthera pardus*, are listed respectively as endangered and near threatened by the International Union for Conservation of Nature (IUCN). These species may face tangible threats by lethal controlling farmers, and consequently require intensive population monitoring in the future. Although tensions between people and conservation authorities exist, my findings suggest that positive attitudes and opinions of both subsistence and commercial farmers towards wildlife and PAs and the willingness of conservation authorities to work with local human communities could be explored as one potential avenue to conserve wildlife. This is with the proviso that these synergies can be fostered into long-term interactions, especially when environmental conditions continue to deteriorate and human population expansions endure.

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