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Faculty of Tropical AgriSciences

Carnivore-livestock conflict in Southern Namibia

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled ‘‘Carnivore-livestock conflict in Southern Namibia’’ independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague the 23rd of April 2021

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Clara María Koch Jiménez

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Abstract

Carnivore-livestock conflict is a worldwide ongoing problem that affects farmers livelihoods and carnivore conservation. In order to mitigate the dispute, a deep understanding of the social and ecological factors that drive it is necessary. This study investigated attitudes of farmers in South-eastern Namibia towards carnivore species as well as the impact of livestock protection techniques on carnivores' distribution and abundance. These two objectives were carried out with informal interviews and closed questionnaires, along with a camera trap survey covering a protected wildlife reserve and its three surrounding farms. Using two main descriptors of species' presence - occupancy and camera trapping rate- it was found that carnivores' populations were affected by livestock husbandry. Black-backed jackals, brown hyaenas, honey badgers and leopards were only found in the reserve, whereas wild cats and cape foxes were distributed in both areas. The abundance of cape foxes did not differ between the areas, whereas the wild cats' abundance was slightly higher within the wildlife reserve. Questionnaire results showed that attitudes towards these carnivores were in general negative, especially for jackals and caracals, the most conflictive and removed species. Although the proportion of livestock losses attributed to predators were high, they did not correlate with the level of conflict. Results showed that the use of preventive husbandry such as fences, herders, dogs, or night enclosures served to reduce carnivore predation. These findings provide insight into the conflict and suggest that interventions aiming to improve attitudes towards carnivores should focus on education, the use of livestock protection techniques, and the implementation of game use and trophy hunting activities as alternative income sources.

Key words: farmers, questionnaires, camera trap, attitudes, distribution

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List of the abbreviations used in the thesis

AIC: Akaike Information Criteria

CTAP: Camera Trap Analysis Package

CTR: Camera Trapping Rate

IUCN: International Union for the Conservation of Nature

LC: Least Concern

MET: Ministry of Environment and Tourism

NT: Near Threatened

SE: Standard Error

SPSS: Statistical Package for Social Science

VU: Vulnerable

1. Introduction and Literature Review

We are living in the Anthropocene, a period on Earth history in which humans are having meaningful large-scale effects over climate and the environment. Its beginning is linked with the Industrial Revolution as it significantly improved living standards and, with the development of medicine, implied an exponential growth of the human population. Since then and in order to meet needs, humans have largely expanded borders and exploited resources. Activities such as deforestation, land-use changes and fossil fuel burning have been accelerated (Ehlers & Krafft 2006). Changing habitats to humans' benefit while sharing the natural common space with different animal species has led to an inevitable increase in competition with wildlife.

Wildlife conflict is a complex widespread issue that has received attention in a large number of publications. In a wildlife-conflict literature review (Redpath et al. 2014) it was shown that most of the involved species were predators -carnivores- and large herbivores, and that the conflict started when there were conservation objectives plans against mainly livelihood or human's safety objectives. Some negative impacts of wildlife on people are attacks on humans, transmission of diseases, predation of livestock and game, and crop-raiding. While the previous were direct costs, wildlife also inflicts indirect costs in respect of money and time spent in preventing wildlife damage (Woodroffe et al. 2005).

Solutions towards solving the conflict have been argued by many scientists (Woodroffe et al. 2005; Sillero-Zubiri et al. 2007; Blackwell et al. 2016) and there is a common agreement in that there is not a single solution to the problem. A mixture of technical strategies together with a multidisciplinary approach based on the dialogue of the different affected parts and a comprehensive study of each case are necessary to mitigate the conflict.

1.1. Attitudes towards carnivores

How humans relate with carnivores has been since prehistoric times two sides of the same coin: they have been used as resources and valued as noble species on one hand, and on the other hand, conflicts have arisen due to their attacks on people and livestock, predatory behaviour, and transmission of diseases.

Negative attitudes towards carnivores are predictors of human-carnivore conflicts and are linked to factors like age, source and level of income, culture, and religious beliefs (Kellert 1985; Schumann et al. 2012; Thorn et al. 2015). Studies performed on wolves (*Canis lupus*) showed negative attitudes in correlation with age, rural residence, and farming occupation, and positive in correlation with higher education and income (Bjerke et al. 1998; Williams et al. 2002). In general, it is observed that farmers report high conflictive levels with carnivores, and it is understandable that negative attitudes are found in groups that are affected economically by these animals. However, not all negative attitudes towards carnivores are related to predatory behaviour. Several studies have found that other factors such as fear, hostility from past experiences, and cultural attributes were the drivers of negative attitudes more than livestock losses (Dickman 2010; Thorn et al. 2015; Mkonyi et al. 2017). This shows a different perspective in which scientist and managers should pay more attention in order to mitigate carnivore conflicts.

Fear is an important factor in human-carnivore conflicts that can shape attitudes towards carnivores. Fear arises from uncertainty and amplifies how people perceive a risk (Slovic & Peters 2006). Consequently, humans tend to persecute carnivores regardless of their density or their real threat to peoples' livelihoods (Ginsberg 2001). The willingness to pay for management and conservation of large carnivores also decreases with levels of fear (Johansson et al. 2012). Different categories of intervention have been proposed to reduce fear-related problems, such as education, animal exposure, participation and collaboration between stakeholders, and financial incentives. However, the effect of these interventions in literature is scarce and contradictory, being difficult for managers to rely on such results (Johansson et al. 2016).

On the other hand, positive attitudes have been primarily found among wildlife managers, biologists, or the general public. These attitudes were related with concerns for the environment, and other values such as curiosity, excitement, and variation in life (Kaltenborn & Bjerke 2002). Positive attitudes towards wolves among the general population accounted for 61% after a literature review performed by Williams et al.

(2002). However, this number seemed to lower in less developed countries. Positive attitudes from Tanzanian local people towards carnivores accounted only for 20%, addressing either that there were no problems with carnivores, that carnivores were important to keep around or that profit was generated from tourism (Dickman 2005; Mkonyi et al. 2017). Another study in Kenya with livestock farmers stressed the importance of receiving income from ecotourism or trophy hunting as a way of increasing tolerance towards carnivores (Romanach et al. 2007).

1.2. Conservation and ecological role of large carnivores

Another impact of human behaviour during the last decades has been the reduction of biological diversity; an irreversible process that affects nutrient cycling and decreases productivity and stability of ecosystems (Cardinale et al. 2012). Major threats that large carnivores are facing are habitat loss and fragmentation, human population growth, depletion of prey, unsustainable trophy hunting and persecution by humans associated with livestock predation (Mkonyi et al. 2017). Carnivores are especially vulnerable and are rather difficult to preserve due to their large home ranges, low densities and reproductive rate, and their competition with human for resources, entering in conflict with them. Cardillo et al. (2004) showed that particularly carnivores present a higher extinction risk as their intrinsic biological traits place them in a week position to withstand threats and recover rapidly from depletion.

As a consequence of this, carnivore population sizes and distributions are declining. From the thirty-one largest species from the order Carnivora, 61% are listed as threatened by the International Union for the Conservation of Nature (IUCN) and 77% are undergoing population declines (Ripple et al. 2014). To mention some examples, leopards (*Panthera pardus*) are categorized as vulnerable species and have suffered a 61% reduction in their historical range. South African countries hold now the healthiest population of their entire range (Stein et al. 2020). Brown hyaenas' (*Hyaena brunnea*) range has also shrunk significantly since the end of the 18th century and it is considered now Near Threatened as the population size has declined in the last years due to deliberate and incidental persecution (Wiesel 2015).

While persecution and loss of prey are short-term threats, land conversion is probably the greatest long-term threat to carnivore conservation (Ginsberg 2001). Consequently, protected areas become important refuges to many large carnivore species. However, most protected areas are too small to accommodate viable carnivore populations, and predators extend themselves into multiple-use landscapes where they enter into conflict with humans (Breitenmoser et al. 2012). The major cause of carnivore mortality in small, protected areas arises from conflict with people on reserve borders, particularly in relation with livestock predation. Especially species that range widely -irrespective of population density- are most likely to disappear from small reserves as they are more exposed to these threats (Woodroffe & Ginsberg 1998). Co-occurrence of carnivores and humans is then frequent outside protected areas and coexistence is necessary for successful carnivore conservation. Coadaptation is crucial to achieve coexistence, meaning that humans and carnivores should change their behaviours and seek their own interests causing minimal negative impacts to each other (Treves & Karanth 2003; Carter & Linnell 2016).

If coexistence and conservation measures fail, it can lead to the eradication of carnivore species. Despite some controversy across the scientific community (Halaj & Wise 2001; Ford & Goheen 2015), a wide range of research has established that carnivores present powerful top-down cascading effects that can affect the whole ecosystem (Winnie Jr & Creel 2017). Classically, the effect is known to extend down to herbivores and to plants. Predation by large carnivores has direct effect by limiting densities of mammalian herbivores, and indirect effects by shaping their physiology and behaviour by creating landscapes of fear (Ripple & Beschta 2012; Gallagher et al. 2017). Subsequently, where predators have been extirpated herbivore densities increase and impact plant communities by expanding into new territories and increasing plant damage. The plant community, in turn, influences other groups like birds, mammals and insects (Miller et al. 2001; Atkins et al. 2019). A well-known (although still controversial) example of top-down regulation by carnivores is the reintroduction of wolves into the Yellowstone National Park, where reintroduction of wolves was correlated with decreasing browsing and elk density, an increase in aspen recruitment, and changes in the structure of the landscape (Beschta & Ripple 2006; Painter et al. 2018).

The effect is not solely focused on prey species, but it also affects mesocarnivores through their competition with them. If an apex carnivore species is removed, this might be compensated by the growth of other carnivore species -called mesopredator release- or the eventual colonization by a guild competitor (Ginsberg 2001; Ritchie & Christopher 2009). This was observed by Crooks and Soulé (1999) in where the loss of an apex predator led to the increase in abundance of smaller predators and the local extinction of avifauna.

1.3. Carnivores-livestock conflict

Carnivores are animals with high protein requirements and large home ranges, which leads to competition with humans as they share similar needs (Treves & Karanth 2003). Many large carnivores are specialised in ungulate depredation and are able to switch to livestock predation if the opportunity arises (Valeix et al. 2012). Carnivore-livestock conflict is a worldwide problem; from bears (*Ursus* spp.) and wolves in Europe and North America, to tigers (*P. tigris*) in Asia, and lions (*P. leo*) and jackals (*Canis* spp.) in Africa.

Livestock predation was the most cited cause of human-wildlife conflict in a questionnaire sent to scientists that were involved in carnivore conservation (Sillero-Zubiri & Laurenson 2001). While in many cases predators prefer wild ungulates over livestock as prey, the switching can happen when wild prey is scarce (Meriggi & Lovari 1996; Valeix et al. 2012). In times of scarcity, livestock becomes an abundant, available, and vulnerable prey as they lost their anti-predator behaviour. In addition, livestock can outcompete wild prey and change their abundance or behaviour as they compete for the same resources (Sillero-Zubiri & Laurenson 2001).

Although relatively little livestock is preyed from the total stock holding, the economic cost of carnivore predation can represent a significant impact on farmers livelihoods. In Zimbabwe, the annual loss per household due to predation was 12% of their annual net income (Butler 2000). In Namibia, the annual cost of carnivore presence accounted for US$ 3461 per person (Rust & Marker 2014).

Previous studies dealing with carnivore-livestock conflicts in Africa have focused on assessing human attitudes. Most studied species have been large carnivores such as wild dogs (*Lycaon pictus*), cheetahs (*Acinonyx jubatus*) and lions (Marker et al. 2003; Hemson et al. 2009; Mkonyi et al. 2017). Less attention has been given to mesopredators or smaller carnivores, probably because of being less charismatic to preserve or their lower position in the trophic food web and thus lesser conflict degree with livestock. However, even in the presence of large predators, they can be source of great conflict (Thorn et al. 2012).

1.3.1. Reducing the conflict

Many solutions have been proposed to mitigate carnivore-livestock conflict. Lethal control -by hunting, gin traps or poison- has been the oldest method of choice, but the total eradication of a conflictive species clashes with conservation plans. Selective removal of “problem animals” (i.e. individuals that are causing the attacks) has been a common approach. However, there are many logistical problems linked to targeting and removing them, and even so, their territories can be rapidly filled with other individuals (Linnell et al. 2012). To avoid encounters with carnivores zoning has been proposed as an approach that aims to separate geographically livestock from carnivores into different areas with different management priorities (Linnell et al. 2005). However, it would not exclude carnivores from every zone, and its implementation would require large areas to ensure conservation goals. To prevent access to livestock, light and sound devices have been used to scare carnivores. Nonetheless, it turns out to have a temporary effect as carnivores become habituated (Shivik 2006).

Other approaches have been focused on changing the behaviour of both carnivores and humans (Treves & Karanth 2003). Carnivore behaviour can be modified by using non-lethal methods such as taste and olfactory agents that are linked with negative experiences (e.g. induce vomiting chemicals on carcasses). However, this method has seemed to fail on many occasions as individuals continued with the killing (Sillero-Zubiri & Laurenson 2001). Human behaviour modification includes changing of husbandry and guarding practices; for example, the incorporation of a guarding dog or herder to supervise the new-borns, enclosing the animals at night, fencing the grazing area, allowing wild prey to recover to reduce pressure on livestock, or changing the livestock farmed to a larger species to reduce predation by smaller carnivores (Sillero-Zubiri & Laurenson 2001; Linnell et al. 2012).

From the mitigation measures mentioned before, two of them have shown to produce effective results: electric fencing and shepherding systems. Electric fencing has proven to be very effective at discouraging carnivores from entering fenced areas. It requires a high initial investment but low maintenance costs. Even though some carnivores can still enter (through jumps or excavated holes), killings are heavily reduced. The biggest disadvantage is that it disrupts the migration and movement of wildlife (Linnell et al. 2012). Shepherding systems protect livestock by the presence of a shepherd -often escorted by a dog- during the day, and by a closed corral during the night. This traditional system has suffered little change since history and many studies have shown its success (Schiess-Meier et al. 2007; Gusset et al. 2009; Lindsey et al. 2013). The main problem of this method is that it is high labour demanding.

Economic assistance has been also proposed to mitigate the conflict. Either in form of post-mortem compensation schemes, incentives to adopt new husbandry methods, insurance schemes or payment for the mere presence of carnivores (Linnell et al. 2012). Although payment for compensation losses is widespread, it does not always help to mitigate the conflict (Gusset et al. 2009; Boitani et al. 2011) as it does not motivate farmers to adopt other mitigation strategies.

Lastly, lowering the costs associated with carnivores through trophy hunting or ecotourism has been effective in alleviating negative attitudes (Sillero-Zubiri & Laurenson 2001). Lindsey et al. (2013) showed that tolerance towards carnivores was higher when income from wildlife was higher and income from livestock was lower. In Namibia, commercial livestock farmers have started to use trophy hunting as an alternative source of income (McGranahan 2011).

1.4. Farming in Namibia

Farming is a big enterprise in Namibia with 78% of the country used for this purpose. Although its contribution to the GDP is low -average of 3 to 5%-, the agricultural sector remains one of Namibia’s biggest employers. While fishing is the largest contributor, livestock farming occupies second place, followed by crop farming. (Nangolo & Alweendo 2020)

Livestock farming is mainly comprised of commercial or freehold cattle farms in the north, and small stock farms -sheep and goats- in the west and south. The small stock freehold farms consist of 2,000 farm units of extensive production from which farmers receive their main source of income. Sheep is the predominant livestock bred in southern freehold farms, raised for their meat production, and sold locally and to South African markets (Mendelsohn 2006).

Day-to-day practices focus on finding food resources, supplying water, and protecting livestock against predators. To fulfil these needs, farms are provided with large terrain extensions, water points and fences. Black-backed jackals (*Canis mesomelas*) are the commonest predators in Namibia to prey on goat and sheep, while wild cats, leopards, and hyaenas represent a threat to chickens, horses, and cattle respectively (Mendelsohn 2006; Rust & Marker 2014).

Namibian law includes certain carnivore species into the categories ‘‘protected game’’ and ‘‘specially protected game’’ on which hunting on private land is forbidden unless owning a special permit from the Ministry of Environment and Tourism (MET). Some species included are wild dogs, cheetahs, leopards, and lions. However, these species can be killed without a permit in defence of human life or to protect livestock if their lives are under threat. In these cases, the responsible person must report the killing in a writing form to the nearest nature conservator or the nearest police office. On the other extreme, there are species categorized as ‘‘problem animals’’, which can be hunted at any time the animal is found. These species are baboons (*Papio ursinus*), caracals (*Caracal caracal*), dassies (*Procavia capensis*) and black-backed jackals (Government Gazzete 1975; Legal Assistance Center 2020).

1.5. Camera traps for wildlife research

Camera traps are remotely triggered cameras that take images or videos when an animal or subjects passes in front of them. The automatic triggering is done with the help of passive infrared sensors that detect changes in heat and motion between the subject and the background temperature. The picture is then illuminated with an infrared/LED flash for visualization, which is more or less visible to the animals depending on the camera model. Camera traps were invented in the late 1890s by

George Shiras and have suffered since then significant technological progress. Nowadays there is a vast range of cameras models in the market with competitive prices and new functions introduced every year (Rovero & Zimmermann 2016).

Camera trapping is widely used to study medium to large terrestrial mammals and birds, and it is also being applied to other groups like arboreal mammals, semiaquatic mammals, small mammals and herpetofauna (Rovero & Zimmermann 2016). They are especially useful in capturing carnivores due to their low density, nocturnal behaviour, and elusive nature. There are many studies that have used camera trapping as the method to assess carnivore populations (Kauffman et al. 2007; Gerber et al. 2010; Pettorelli et al. 2010). A global approach was performed by Rich et al. (2017) in which carnivore occupancy and richness was studied globally by the integration of local camera trap located in 12 countries.

When compared with other wildlife detection methods -such as direct observation, trapping or tracking- camera trapping presents an array of advantages. It offers a less invasive and more ethical way to study wildlife as it causes a minimum disturbance to the animals being studied. As a present researcher is not needed, cameras can be left unattended for weeks and months and be working all day and night. This automatism allows prolonged data collection and the possibility to study remote areas or elusive, rare animals. The greatest advantage they offer is the record of accurate data. Humans direct or indirect -dung, track counts- observations can lead to biased results, whereas camera traps provide hard fact evidence of an animal’s presence and identification, and contrary to live observations, data can be reviewed by other scientists (O’Connell et al. 2011; Rovero & Zimmermann 2016). All these aspects make camera traps a suitable tool to study wildlife. In fact, Silveira et al. (2003) concluded that despite the high initial costs, camera trapping was the preferred method -over line transects and track surveys- to perform a rapid assessment of wildlife status.

However, as shown with other methodologies to study wildlife, camera traps also bear some weak points. One of the biggest fear of scientists using camera traps is the loss of data, which can have a great cost if used in remote locations as it takes time to realize the breakdown. Loss of data can be on account of the inexperience of the researcher (e.g. low battery, wrong attachment of the camera) but can be also due to uncontrolled events like animal damage, theft, weather conditions or damage of the camera itself producing failure of the trigger mechanisms -leading to loss of an animal event- or multiple photographs not containing any wildlife (O'Connell et al. 2011). In addition, the design of the experiment becomes an important feature to plan before the camera traps are set. Without critical thought of the design and in the absence of standardized methods, results can be misleading, and comparison of different studies becomes difficult or almost impossible (Meek et al. 2014).

1.5.1. Application of camera traps surveys

Camera traps are being used in scientific research to study animal behaviour, ecology and conservation. The first camera trap studies were focused on nest ecology and activity patterns; but in recent year the study spectrum has increased as camera traps are now addressing animal behaviour, predation, species distribution, detection of cryptic or rare species, and estimation of population parameters such as abundance, density and occupancy (O'Connell et al. 2011).

For abundance and density-population studies the capture-recapture technique is used in which animals need to be individually identified in order to obtain reliable estimates. This is only possible if the studied animal presents unique identification (e.g. pelage pattern), whereas it becomes challenging in species with subtle markings (Maffei & Noss 2008; Dorning & Harris 2019). In most cases it might be impossible, too resource demanding or unnecessary. Occupancy and camera trapping rate are two variables used in camera trapping studies that determine the presence and distribution of species and can work as surrogates of abundance (Rovero & Zimmermann 2016).

Camera trapping rate (CTR) measures the number of independent events of species captured that occur during the sampling period. It is also known in literature as relative abundance index as it can provide information about the animals' abundance with the assumption that the studied species will trigger cameras in relation to its density (Rovero & Zimmermann 2016; Amin et al. 2017). Carbone et al. (2001) showed that the camera trapping rate was correlated with density estimates of tigers that were performed independently with the capture-recapture technique. Other studies (Rowcliffe et al. 2008) also prove the relationship and support the use of CTR as a relative abundance index. However, this relationship should be treated carefully as CTR is based on the captures but does not account for the probability of the animal being present but not detected by the cameras. Some factors such as body size, home range and behaviour can affect detectability (Rovero & Zimmermann 2016). Thus, comparing CTR between species without taking detectability into account can lead to erroneous conclusions (Sollmann et al. 2013). Detection probability is therefore an important component in determining abundance.

Occupancy refers to the occurrence of a species in an area and accounts for the detection probability mentioned before (MacKenzie et al. 2006). Regarding its relationship with abundance, it can be assumed that the more occupied the area the higher the density/abundance, and vice versa. This works for species with a small (<5-10 km^2) and well-defined home range -in where each individual will appear only in one camera trap- and in cases where the camera trap grid covers a representative fraction of the population. If this is not met, then there will be little correlation between abundance and occupancy (Rovero et al. 2013). One example is the study performed by Kalle et al. (2014) in which small carnivores' abundance and habitat use was studied in a tropical forest in India using the occupancy.

This was just a small approach on what cameras traps can do, especially focused on camera trapping rate and occupancy, commonly used methods that can provide abundance estimators and information about species distribution.

2. Aims of the Thesis

The aim of the thesis is to assess the conflict between carnivores and livestock farmers in South Eastern Namibia, and to comprehend how the current techniques used to protect livestock affect the carnivore population. The final goal is to comprehend and provide insight into the conflict and propose solutions to alleviate the dispute. The results are meant to be used as a tool for conservation, management, and coexistence.

In order to achieve the aim, two main objectives are carried on:

1) The first objective is to gain knowledge about the farmers' attitudes towards the livestock-carnivore problem. This will be carried out with informal interviews and closed questionnaire surveys.

2) Secondly, the distribution and estimated abundance of the conflictive carnivores will be studied within a wildlife protected reserve and three livestock farms that surround it. It will be done with camera traps and calculation of the occupancy and camera trapping rate.

There are many studies addressing attitudes and factors that drive carnivore-livestock conflict; however, little is known about the effects that human persecution and husbandry methods have on carnivores' abundance and distribution. This study aims to address both parts, as it is equally important to understand the sociological as well as the ecological components.

2.1. Hypothesis

1. We predict that there is conflict between carnivores and farmers, and that farmers use methods to avoid and reduce carnivores in their farms.
2. As a result, the distribution and estimated abundance of conflictive carnivores will be higher in the wildlife reserve due to the persecution by farmers inside their farms.

3. Methods

3.1. Study area

The study area is the Karasburg constituency, located on the extreme southern end of Namibia, bordering South Africa with the Orange river (28° 00' 59.7" S, 18° 44' 54.4" E). It has an extension of 38,329 km^2 and belongs administratively to Karas region (Namibian Statistics Agency 2014) (Figure 1).

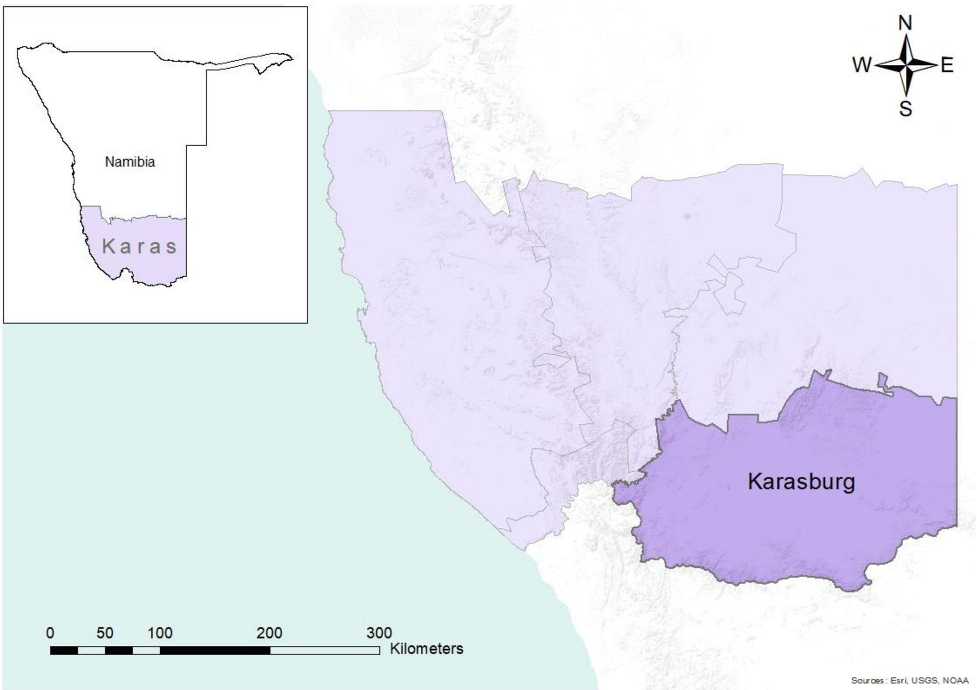

Figure 1. Map of the study area.

The area of Karasburg is found in the South African Plateau which has an elevation of 1,000 to 1,400 meters. In the western border of the constituency the Karasburg sedimentary basin is located, while Karas mountains are found in the north (Dauteuil et al. 2014). The rest of the area is characterized by extensive sandy and rocky plains with isolated hills and hill ranges (Figure 2). The terrain becomes abrupt and sharp along the Orange river basin, in the south.

Figure 2. Picture of the study area showing the predominance of sandy plains. In the background hill ranges can be observed.

Geologically speaking it is quite a heterogeneous region; mainly with complex and sedimentary rocks (sandstones, limestones, shales and calcrete), but also with metamorphic (gneiss), and igneous rocks (granite and volcanic rock) (Owono et al. 2016). The dominant soil of the region is eutric leptosols, which refer to fertile shallow soils that occur in drought areas. As their water-holding capacity is low, these soils can support low densities of livestock and wildlife (Mendelsohn et al. 2002).

The climate is classified as continental hot arid desert (Beck et al. 2018). Summers are hot (>30 ºC), and winters cold with temperatures close to zero. The mean annual precipitation ranges from less than 50 to 150 mm. Rainfall occurs during late summer (December to April) with peaks in March. Droughts are unpredictable and intervals between them sometimes prolonged for years. Apart from the Orange river, most rivers are non-perennial. While dust storms are uncommon, dust devils are frequent in summer (Mendelsohn et al. 2002; Mucina et al. 2006).

3.1.1. Flora and Fauna

The area lays in the Nama-Karoo biome, where extensive plains are dominated by low shrubs (<1 m tall) intermixed with grasses, succulents, geophytes and annual forbs. Small widely scattered trees occur along drainage lines or rocky outcrops. The Nama Karoo supports a diverse assemblage of plant communities, from deciduous and succulent shrubs to perennial C_3 and C_4 grasses and ephemerals (Mendelsohn et al. 2002; Mucina et al. 2006). Dominant Poaceae grasses include *Schmidtia kalahariensis*, *Stipagrostis ciliata*, *Stipagrostis obtusa*, *Cladoraphis cyperoides*, and *Fingerhuthia africana*. Succulent shrubs from genus *Euphorbia* can be found (*E. dregeana*, *E. gregaria*), as well as non-succulent taller shrubs such as *Sisyndite spartea*. Predominant scattered low trees are *Aloidendrum dichotomum* and *Acacia mellifera* (Muller 1983).

Mammals from the order Carnivora found in the area include the leopard, caracal, African wild cat (*Felis silvestris cafra*), small-spotted cat (*Felis nigripes*), brown hyaena, aardwolf (*Proteles cristata*), black-backed jackal, Cape fox (*Vulpes chama*), bat-eared fox (*Otocyon megalotis*), and smaller carnivores such as the honey badger (*Mellivora capensis*), striped polecat (*Ictonyx striatus*), Cape clawless otter (*Aonyx capensis*), small-spotted genet (*Genetta genetta*), and mongooses (family Herpestidae). Sightings of greater kudus (*Tragelaphus strepsiceros*), steenboks (*Raphicerus campestris*), and springboks (*Antidorcas marsupialis*) are common; other ungulates found are the mountain zebra (*Equus zebra hartmannae*), common eland (*Taurotragus oryx*), gemsbok (*Oryx gazella*), red hartebeest (*Alcelaphus caama*) and klipspringer (*Oreotragus oreotragus*). In the area also primates can be seen like the vermet monkey (*Chlorocebus pygerythrus*) and the chacma baboon (*Papio ursinus*). Aardvarks (*Orycteropus afer*), hyraxes (*Procavia capensis*), bats and rodents -such as mice, elephant shrews (family Macroscelididae), hares (*Lepus capensis*), rabbits (*Pronolagus rupestris*), springhares (*Pedetes capensis*), ground squirrels (*Xerus inauris*) and porcupines (*Hystrix africaeaustralis*)- are also present in the area.

As for the birds, small Passeriformes are commonly observed: flocks of sociable weaver (*Philetairus socius*), cape sparrow (*Passer melanurus*), cape bunting (*Emberiza capensis*), karoo scrub robin (*Cercotrichas coryphoeus*), bokmakierie (*Telophorus zeylonus*), flycatchers (family Muscicapidae), chats and wheatears (*Cercomela* spp., and *Oenanthe monticola*), canaries (*Crithagra* spp.) and larks (family Alaudidae). Crows

(*Corvus albus*, *Corvus capensis*) are frequent in the area together with sandgrouses (*Pterocles* spp.), doves (*Columba* and *Streptopelia* spp.) and korhaans (*Afrotis afraoides* and *Eupodotis vigorsii*). Raptors can also be seen, like the pale chanting goshawk (*Melierax canorus*), spotted eagle-owl (*Bubo africanus*), black eagle (*Aquila verreauxii*) and vultures (*Torgos tracheliotus* and *Gyps africanus*).

Reptiles are also prevalent, including geckos (*Chondrodactylus* and *Pachydactylus* spp.), agamas (*Agama* spp.), lizards (*Pedioplanis* spp.), skinks (*Trachylepis* spp.) and snakes (*Bitis*, *Naja* and *Psammophis* spp.) (Franco-Polo 2020).

3.1.2. Land use

Land ownership is divided into three main categories: central government, local authorities, and private individuals or companies. Most of the land in Karasburg is privately managed (Figure 3), in which owners enjoy using the land for any purposes within the local regulations (Mendelsohn et al. 2002).

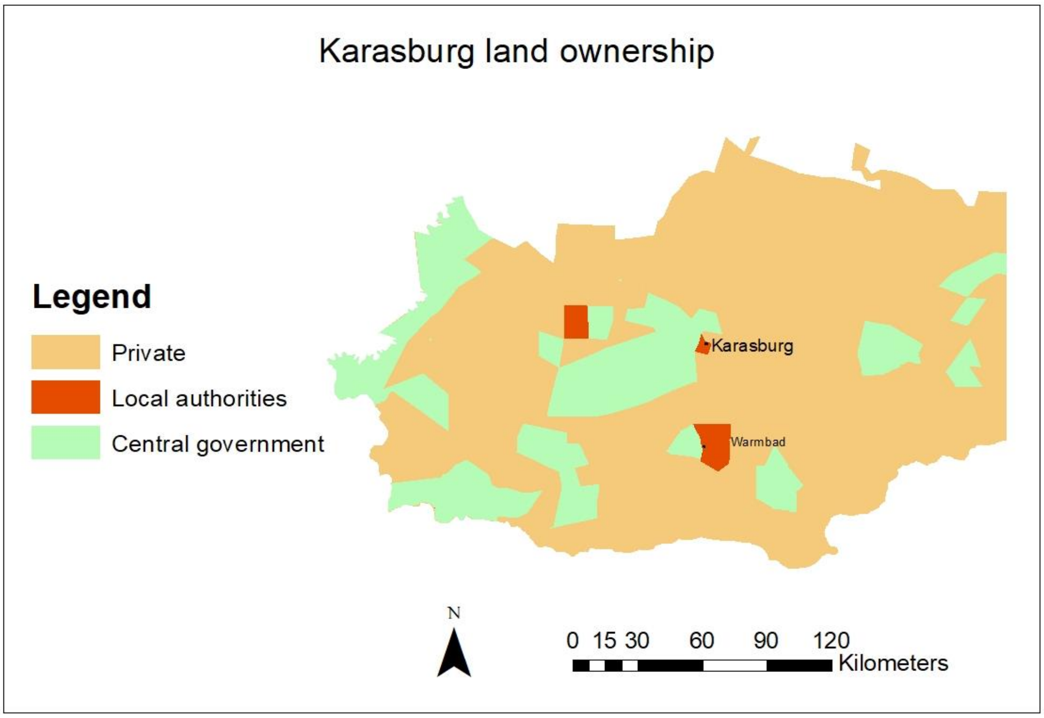

Figure 3. Map of the different land ownership in Karasburg constituency. Source from Acacia Project E1 (2002).

The main land use of Karasburg is the ranching of small stock (wool and mutton sheep), being Karakul and Dorper the predominant sheep breed. Their densities range from 1 to 20 numbers per km^2. Most of the lamb and mutton produced from these sheep is sold locally or/and to South Africa. After sheep, the most frequent farmed livestock are goats and cattle; with respective densities of 0-10 and 0-5 individuals per km^2 (Mendelsohn et al. 2002). Ranches are fenced and generally large (between 40 and 150 km^2) as it takes 0.1-0.5 km^2 to support one head of cattle or seven sheep. Animals graze extensively and rotate within the camps (Mucina et al. 2006).

One large, protected area is found in the western border of the constituency, the Ai-Ais Hot Springs Game Park, a labyrinth of rugged valleys and high mountains where the largest canyon in Africa is found, the Fish River Canyon. Besides this protected area, other large areas have been declared as conservancies; defined as private farmlands or communal lands where natural resources are managed and protected. As an example, the western part of Karasburg city is a conservancy area being planned; also, many private farms are managed as nature reserves, generating incomes by tourism and/or game hunting and game meat products. A considerable number of other farms mix livestock farming with some of the conservation activities mentioned before (Mendelsohn et al. 2002).

3.1.3. The People

With 3.1 persons per square kilometre in 2020, Namibia ranks second place among less populated countries worldwide (United Nations 2019). As we travel south and move away from metropolitan areas, the population density decreases. In the latest census carried out in 2011, the total population of Karasburg constituency was 16,470 people, presenting a density of 0.4 persons per km^2 (Namibian Statistics Agency 2014).

The median age of the Karasburg population is 26 years, an indicator of an intermediate population, with 65% of it ranging ages 15-59. Regarding the socio-economic aspect, 97% of Karasburg population older than 15 year is able to read and write, but 85% of it (15+ years) left school. Employment is present in 71% while the majority of households (60%) are headed by a man. Regarding the agricultural activity as a source of income, livestock farming is the most common, followed by crop, and poultry (Namibian Statistics Agency 2014).

3.2. Data collection

3.2.1. Camera trap survey

The field work took place during July and August of 2019, throughout the Namibian winter. Twenty camera traps (fourteen UoVision UV535, three BTC-6PXD, one BTC-5PXD and two SiFar 3.0C) were placed in the field from July 8th to August 19th. The camera trap survey was carried out on the top south of Karasburg constituency, in a private wildlife reserve and three neighbouring livestock farms. They are quite isolated areas as the closest settlement is Warmbad, located 37 km away, and Karasburg with 85 km distance.

The private wildlife reserve holds quite a heterogeneous landscape, (Figure 4) with mountainous abrupt regions, low hills, and rocky and sandy plains. In the past the area was used as a game ranch for hunting activities, but since 2012 it was bought by Dr. Peter van der Byl Morkel and Ian Craig in order to create a nature reserve (Mikslová 2019). The area possesses several water points and is fenced along the outside border as well as some interior areas. The current management focuses on removing the excess fences within the area in order to mitigate food depletion by animals moving freely through the land.

The landscape of the neighbouring livestock farms is more uniform. The farms cover the northern face of the mountain also present in the wildlife reserve but present sandy plains in most of their area. The three farms (1. Northwest, 2. North and 3. East) (Figure 4) are privately managed by three Namibian owners and count with water points and external fences along the border together with internal ones to manage and separate their livestock. Sheep is the main and most farmed animal, although goats and cattle can also be found. Depending on the grazing pressure and vegetation, farmers move their livestock within the farm looking for the best food sources. In cases of harsh years when food is scarce, fodder can be supplemented; yet in general no supplementation is given, only lick blocks containing minerals. To avoid carnivores there are different management methods used by farmers, being electrical fencing the most common.

In order to make a comparison between the two different managed areas and to avoid any biased results due to habitat covariates, the criteria of the working area selection (type of terrain and extension) was the same in the wildlife reserve and in the farms. For the first criteria, a previous examination of the terrain was done using satellite images and on-site exploration. As sandy plains were the dominant landscape of the farms, this terrain was also selected in the wildlife reserve. Regarding the second criteria, all the area was selected in the reserve, however, as the extension was considerably bigger in the farms the plains selected were the ones containing sheep at the moment of the survey. This was done by asking the farmers the exact location of the animals. The total working area was 104 km^2; 52 km^2 in the wildlife reserve and 52 km^2 in the farms (22 km^2 in the northwest and northern farm and 8 km^2 in the eastern one) (Figure 4). In order to obtain the sampling points a grid of 2 km^2 cells was created and placed over the map of the working area. The selection of such small grid cells was to ensure small range individuals to be photographed, as this survey was complementary to another master thesis (Andres-Criado 2020), in which small carnivores with lower ranges were studied. Ten squares were then randomly selected from the grid within the wildlife reserve, and another ten divided in the three farms (4 in the northwest, 4 in the north, and 2 in the easter farm, according to the working area extension).

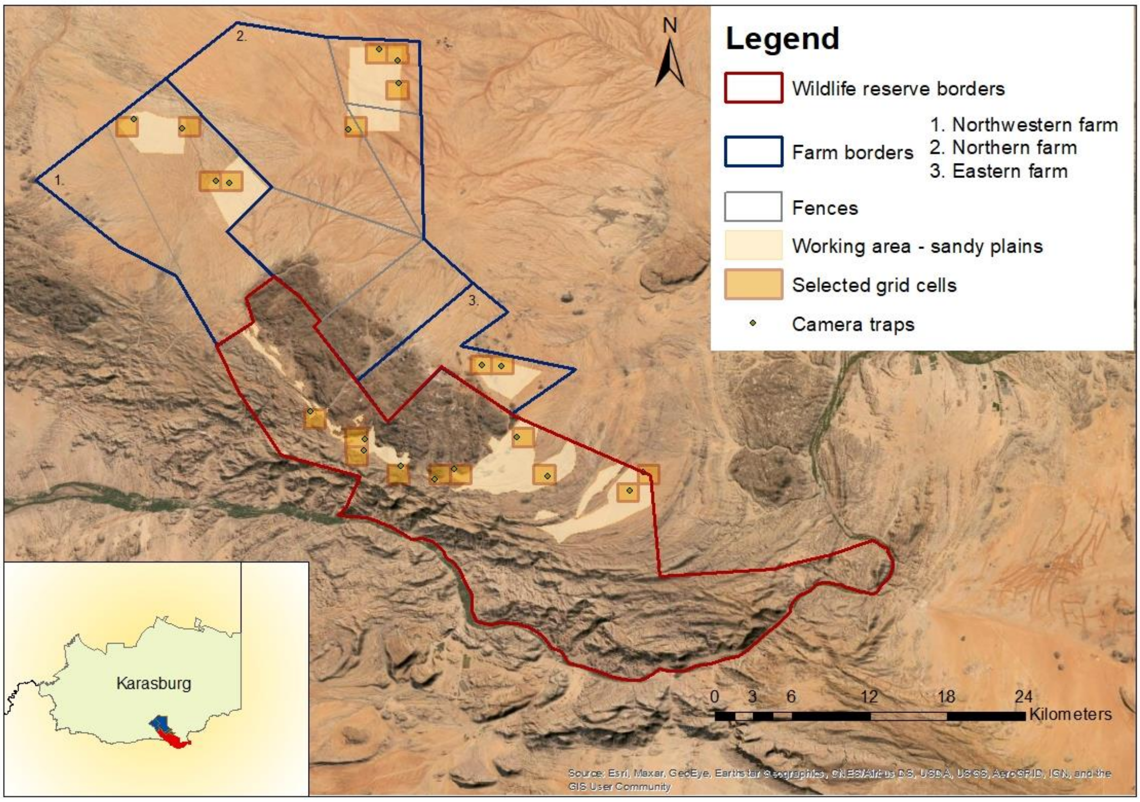

Figure 4. Map of the camera trap survey. Red lines represent the wildlife reserve borders while blue lines shape the three different farms. The working area is shown by a paler colour. Camera traps were placed inside the randomly selected grid cells.

Inside each cell and with a minimum distance of 1 km between camera stations, the infrared-triggered camera traps were placed on sites with a higher probability of encountering wildlife, such as waterholes, dry riverbeds or marked path routes. Either a tree, a rock pile or a metal pole was used to secure the camera trap, which was placed at approximately 50 cm from the ground and at a correct angle to avoid triggering by the sunrise or sunset. The vegetation laying in front of the camera was also removed to avoid unnecessary triggering. To increase the probability of carnivores passing through the cameras' range, a bait made of sardines and tuna oil was placed few meters in front of the camera. Although there has been some controversy in the usage of edible baits (Rocha et al. 2016), their usage is broadly practised and studies have shown how they can be an important tool to attract carnivores and elusive species and improve their detectability (Satterfield et al. 2017; Mills et al. 2019; Ferreira-Rodriguez & Pombal 2019).

The cameras were set to take three photos per movement trigger and to be working throughout the day. The exact position of the cameras was recorded with the phone application Geo Tracker 4.0.2.1750, and the time of the turning on of the camera was documented before leaving the place. Every 6 to 14 days a check-up of every camera station was performed; the right position and working activity of the camera were verified, batteries were changed if necessary, the bait was replaced to keep the odour, the pictures were saved into an external hard drive and deleted from the camera memory card, and finally if needed, the setting of the camera was changed in case there was an abusive number of pictures due to vegetation movement. Dates and times were saved from a total of three services -the last one being the recovery-.

3.2.2. Questionnaires

Questionnaires were prepared during August 2019 while conducting the camera trap survey. After getting to know the three farmers, a friendly environment was settled before asking them questions. Several themes were covered in an informal way, such as the type of livestock present, the monetary gain per head and loss due to carnivores, the most conflictive carnivore species, the management methods present in the farms, etc. All these preliminary results were helpful in order to create the final questionnaire and to analyse the camera trap survey, as to which carnivore species the study had to focus on.

The dissertation thesis performed by Schumann (2009) which deals with human-carnivore conflicts in Namibian farmers was used as guidance to create the questionnaires. These include single and multiple-choice questions as well as open and matrix questions. Questionnaires when then structured into three parts. Firstly, personal information about the farms was asked, such as the size, terrain or livestock hold. The second part was focused on the carnivores; the level of conflict, the perception towards them, the methods to remove them, etc. Finally, questions about the management were asked; like the effective methods used to avoid carnivores or compensation schemes focus on carnivore losses. The first version of the questionnaires was written in English and can be found in the Appendix 1. The last version was then translated to Afrikaans and presented to the farmers on the 19th of November in Karasburg city during their last meeting of Namibia National Farmers' Union of 2019.

3.3. Data analysis

3.3.1. Camera trap survey

Data from the camera traps were analyzed with the software from the Zoological Society of London called Camera Trap Analysis Package (CTAP). This software can manage and process large volumes of image data and translate them into outputs for monitoring the status of wildlife species. Some of the analysis included are species richness estimates, spatial-temporal plots, trapping rates, occupancy and detection probability estimates, and activity plots (Amin et al. 2017).

To import the dataset into the CTAP software, few templates had to be prepared in advance. First, information regarding the camera setups was filled in, i.e. camera configuration, location and services. The next step was to include the information from the photographic images. For this, the Picture Information Extractor software was used to extract from each picture the date, time, and identification number of the image into an excel sheet format. Then every picture was viewed and classified manually in the excel sheet by writing the photo type, i.e., wildlife, livestock, blank, etc. After finishing this long task -24,700 pictures were classified-, the templates were transformed into .csv format and were ready to be imported into the CTAP software to calculate the camera trapping rate and occupancy.

Two different surveys were created in CTAP: one for the wildlife reserve and another one for the three farms, each of them with their correspondent templates. Before running any analysis, two parameters had to be defined. For the trapping rate calculation, only those days were used when at least 75% of the cameras were working. In addition, the duration of an event -time interval between two independent pictures- was set to 60 minutes.

Camera trapping rate

The camera trapping rate (CTR) is defined as the photographic event rate; this means, the number of photographic events at which a species is trapped during the sampling effort. It is calculated as the ratio events/sampling period times 100 and the unit is mean number of events per trap day times 100 (Rovero & Zimmermann 2016; Amin et al. 2017). The sampling period is usually measured in camera days, and an event is an interval of time in which pictures taken within a short time interval are considered dependent pictures and are all condensed into a single independent detection i.e. an event (Sollmann 2018). Most used event intervals are of 30 minutes to 1 hour. In this case as mentioned before, events were set to 60 minutes.

For the statistical analysis, the software IMB SPSS 27 Statistics was used (Statistical Package for Social Science). The significance level was set at 0.05 and a Shapiro-Wilk test was performed to see if the data were normally distributed (Ghasemi & Zahediasl 2012). As it was not the case, a Mann-Whitney U test was performed to observe any statistical differences.

Occupancy

Occupancy is defined as the proportion of an area that is occupied by a species. It can be formulated as the naïve occupancy and the modelled occupancy. The first one is defined as the number of cameras at which a species is detected divided by the total number of operational cameras. The second one -modelled occupancy (ψ)- integrates the concept of detectability, which refers to the common fact that a species can go undetected in a survey. As a result, the modelled occupancy is the naïve estimate corrected by the detection probability (P) (i.e. the likelihood that a species was detected when present) (MacKenzie et al. 2006; Amin et al. 2017). Within CTAP, occupancy (ψ) is analysed separately in the R statistical software (Fiske & Chandler 2011) where samples (days) are grouped into x-day periods (as the sampling occasion) to improve detection probability of the rarer species. A detection (1), non-detection (0) matrix for each species is then constructed for the survey. In other words, occupancy models estimate the proportion of an area where a species occurs while simultaneously estimating the probability of detection through repeated surveys of each site. The naïve occupancy is then adjusted using *P* to estimate ψ (Neilson et al. 2018). The modelled occupancy (ψ) is therefore a more rigorous index of abundance for within and between species comparisons as it considers the detection probability.

The CTAP software uses the single season analysis proposed by MacKenzie et al. (2006) to estimate the occupancy (ψ). Some parameters needed to be set before running the analysis. Survey occasions vary in occupancy studies from 1 to 15 camera-days with a median of 5 days (Burton et al. 2015). In this study the occasion period was set to 3 days; not too small as it would add too many zeros in the matrix and a low detection probability, and not too high as some event information would be lost. For the date setting the whole study period was used, meaning using all events recorded. Modelled occupancy was not calculated for cases in which the naïve occupancy was 0.1 or smaller. The number of detection thresholds (i.e. number of "1" in the detection-non detection matrix) necessary to calculate the modelled occupancy was left in 5, but was afterwards changed to 1 to obtain results for the wild cat, brown hyaena and honey badger.

3.3.2. Questionnaires

Firstly, all questionnaires were transcribed into an Excel sheet for their organization, calculation of descriptive statistics, and creation of graphs. All the non-answered questions and the ones answered ''I do not know'' were not considered. Because several questions were left blank by the farmers, the capital letter ''N'' mentioned in the results was used to express the sample size (i.e. farmers responding to the question), while the lowercase letter ''n'' was used to express the number of farmers meeting some characteristics (e.g. owning sheep).

For the statistical analysis the software IMB SPSS 27 Statistics was used, and the significance level $\alpha = 0.05$ was set. The Shapiro-Wilk test was used to analyze normality and Mann-Whitney U test was used to compare non-parametric independent samples. Pearson chi square test (χ^2) was used to compare non-parametric categorial variables. If the assumption of 'at least 80% of the expected values should be higher than 5' was violated, the likelihood-ratio Chi-square test was used (McHugh 2013). Lastly, Binary logistic regression was used to test the relationship with binary variables and Spearman's coefficient was used to test correlations within and between non-parametric quantitative and ordinal data.

4. Results

4.1. Informal interviews

Some preliminary results were obtained after performing the short informal interviews with the three farmers owing the farms where the camera trap survey took place. The conflict with some species of carnivores was noticeable. While black-backed jackals and caracals seemed to be the most conflictive ones, they also mentioned annoyance by leopards, brown hyaenas, African wild cats, Cape foxes, and honey badgers. Other larger carnivore species present that did not suppose any conflict were the small spotted cat, aardwolf, and bat-eared fox.

Sheep was the predominant livestock present on the farms and, in order to avoid carnivore attacks, each farm presented its unique way of management (Table 1); while all three presented electric fencing, only one held a herder and a pen for livestock at night. Other management methods used included guard dogs and night hunting.

Table 1. Different management methods used against carnivores and livestock animals raised in the three studied farms.

	1. Northwest	**2. North**	**3. East**
Management	Electric fence Guard dog	Electric fence Night hunt	Electric fence Guard dog Pen during nights Herder
Livestock	Sheep	Sheep, Cattle, Goats	Sheep

4.2. Camera trap survey

The twenty camera traps of the survey were operational during an average of 30.5 ± 2.95 days, giving a total of 610 camera trap days. Overall, 24,388 pictures were taken of which 10,874 (44.6%) contained wildlife photographs. The rest of the pictures were mainly containing livestock (5,175; 21.2%) or were false triggers due to plant movement (4,790; 19.6%). From the wildlife photographs, a total of 1,146 events were recorded. The conflictive carnivore species mentioned before were present in a total of 167 events. With the caracal exception, all conflictive carnivores were observed in the wildlife reserve, while only the Cape fox and African wild cat were found in the farms (Table 2). Although the caracal was not observed in this study, its presence was confirmed in rocky and shrubland habitats in the wildlife reserve in a complementary study carried out during the same sampling period (Andres-Criado 2020).

Table 2. Conflictive carnivore species observed in the wildlife reserve and the three farms. Home ranges reference from Kingdon & Hoffmann (2013) and status from IUCN (2021).

		Observed wildlife reserve	Observed farms	Home range (km^2)	IUCN status
African wild cat	*Felis silvestris cafra*	✓	✓	6-10	LC
Black-backed jackal	*Canis mesomelas*	✓	✗	3.5-25	LC
Brown hyaena	*Hyaena brunnea*	✓	✗	220-480	NT
Cape fox	*Vulpes chama*	✓	✓	1-5	LC
Caracal	*Caracal caracal*	✗	✗	79-440	LC
Honey badger	*Mellivora capensis*	✓	✗	126-541	LC
Leopard	*Panthera pardus*	✓	✗	180-230	VU

4.2.1. Camera trapping rate

The total number of days in which more than 75% of the cameras were operational resulted in 28 for the wildlife reserve and 26 for the farms. The Camera trapping rate results are presented as the average number of independent photographic events per trap day times 100. The average and standard error of each conflictive carnivore species are shown in Table 3.

Table 3. Mean camera trapping rate (photographic events 100 day^{-1}) and standard error for the carnivore conflictive species recorded in the wildlife reserve and the farms. P-value results from the Mann-Whitney U test show statistical differences between the two areas.

	Wildlife reserve Mean ± SE	**Farms Mean ± SE**	**p-value**
African wild cat	1.07 ± 0.6	4.13 ± 1.32	0.047*
Black-backed jackal	5.78 ± 1.49		
Brown hyaena	0.84 ± 0.59		
Cape fox	26.13 ± 3.22	14.42 ± 2.83	0.005*
Honey badger	0.75 ± 0.52		
Leopard	0.36 ± 0.36		

The carnivore presenting the highest CTR by a great deal was the Cape fox, both in the wildlife reserve as in the farms. This was followed by the jackal and the African wild cat, this last one presenting a higher CTR within the farms. When compared the two different managed areas, both animals -Cape fox and wild cat- showed statistical differences in the CTR values, being lower in the farms for the Cape fox and higher for the Wild cat. Lastly, the brown hyaena, honey badger and leopard were captured in few events only in the wildlife reserve, showing a lower CTR. These results can be better viewed in Figure 5.

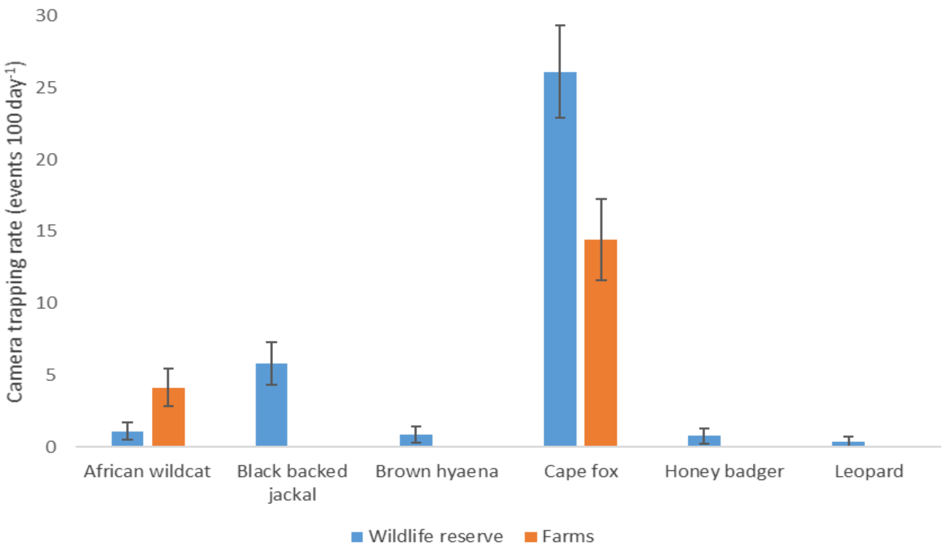

Figure 5. Camera trapping rate mean values and standard errors for conflictive species of carnivores within the wildlife reserve and the farms.

4.2.2. Occupancy

The black-backed jackal and the cape fox were the species detected the most, with a naïve occupancy of 0.8, meaning they were detected in 80% of the cameras. For the Cape fox this value was achieved inside the farms, with a similar value (0.7) in the wildlife reserve. The rest of carnivores presented lower naïve occupancy values, ranging from 0.1 to 0.3, being the leopard the one with least detections appearing only in 10% of the cameras.

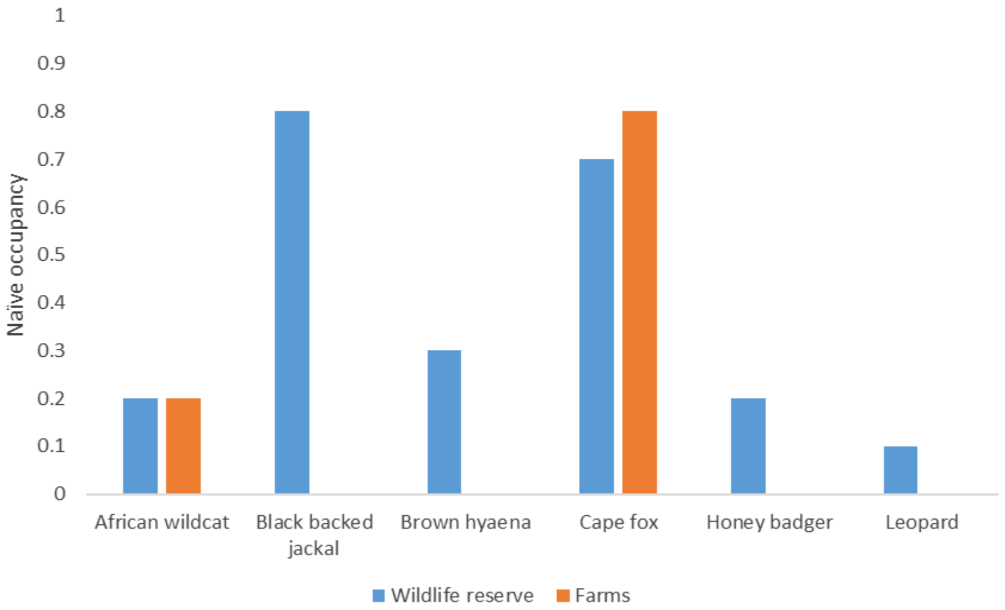

Figure 6. Naïve occupancy of the conflictive carnivore species within the wildlife reserve and farms.

The leopard was the only one excluded from the modelled occupancy as the naïve estimate was too low (0.1). The wild cat, brown hyaena and honey badger presented low detection (3 and 2 events) (Appendix 2), being not enough data for an accurate occupancy estimate. However, the model was forced to obtain some occupancy results (the number of detections necessary to obtain model estimates was set to 1).

The black-backed jackal, brown hyaena and honey badger presented the highest occupancy estimates in the wildlife reserve, with values close to 1 (Figure 7). The Cape fox presented relative high values both in the farms and wildlife reserve, while the lowest occupancy estimate was observed in the wild cat (ψ=0.34 and ψ=0.2).

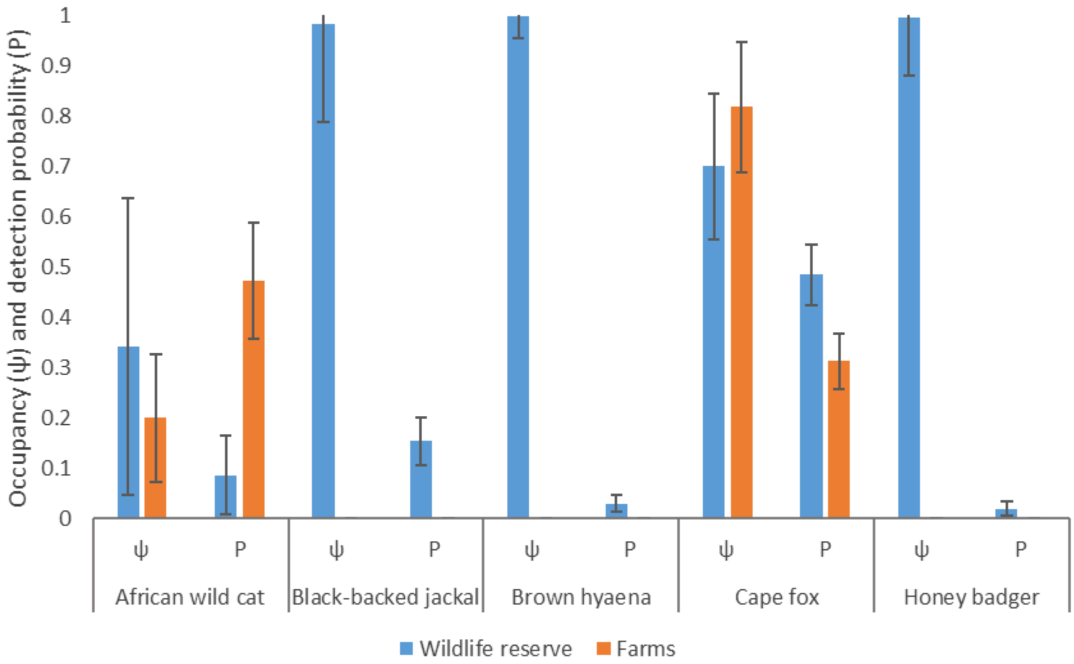

Figure 7. Modelled occupancy (ψ) and detection probability (*P*) for the conflictive carnivore species in both the wildlife reserve and farms. Standard errors (SE) are represented with black lines.

One of the downsides of forcing the model to obtain results for the three carnivores is the resulting detection probability. For the wild cat, brown hyaena and honey badger within the reserve, the detection probability was less than 0.1 (i.e. less than 10% chance of detection). The rest of detection probabilities ranged from 0.15 to 0.49, being the cape fox the highest one.

Differences between the wildlife reserve and farms in terms of occupancy and detection probability varied for the wild cat and Cape fox. While in the farms the wild cat presented lower occupancy and higher detectability, the cape fox presented higher occupancy but lower detectability. Exact values of occupancy and detection probability as well as the model fit can be observed in Table 4.

Table 4. Modelled occupancy (ψ) and detection probability (*P*) values with their SE for the conflictive carnivore species within the wildlife reserve and the farms. The model fit is represented with the AIC values.

	Wildlife reserve			Farms		
	ψ ± SE	***P* ± SE**	**AIC**	**ψ ± SE**	***P* ± SE**	**AIC**
African wild cat	0.343 ± 0.296	0.086 ± 0.078	29.81	0.2 ± 0.127	0.473 ± 0.115	40.29
Black-backed jackal	0.985 ± 0.196	0.154 ± 0.048	88.21			
Brown hyaena	0.999 ± 0.044	0.03 ± 0.017	30.89			
Cape fox	0.701 ± 0.145	0.485 ± 0.061	110.41	0.819 ± 0.13	0.313 ± 0.055	111.5
Honey badger	0.998 ± 0.116	0.02 ± 0.014	23.57			

4.3. Questionnaires

4.3.1. Respondents and farming characteristics

Data were gathered from 15 farmers from the study area. The totality (N=15, 100%) were male with ages ranging from 32 to 70 years old, with a mean age of 50.4 ± 13.5 years. Apart from one foreman, the rest of respondents had the role of owners of the farms (n=13, 92.9%). Farms were privately owned and used for commercial purposes, with sizes that ranged from 68.3 to 500 km^2 and a mean of 191.1 ± 140.1 km^2. The total area of the fifteen farms was 2,867 km^2, covering 7.5% of the whole Karasburg constituency.

Being livestock the main source of income (100%, n=15), other sources that produced revenue were game meat (66.7%, n=10), crops (26.7%, n=4) or trophy hunting (20%, n=3) (Figure 8). When asked about the importance of the income sources present, farmers ranked them from 1 ‘very unimportant to 5 ‘very important’. Livestock stood out with a mean of 4.9, followed by other ($\bar{x}$=4), crop ($\bar{x}$=3.25), game meat ($\bar{x}$=3.1), tourism ($\bar{x}$=2.5) and trophy hunting ($\bar{x}$=2.3).

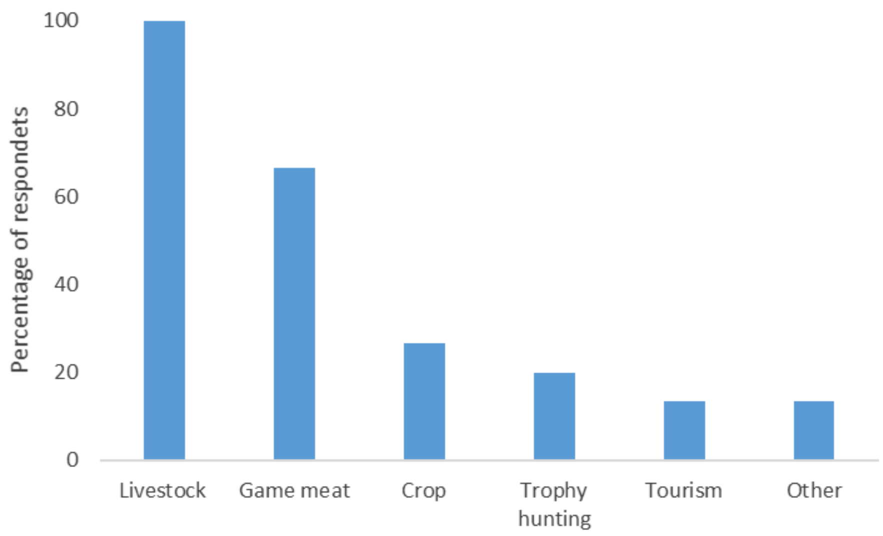

Figure 8. Percentage of farmers using the different activities as income sources.

All respondents farmed sheep (n=15) with an average of 1,220 ± 916 individuals per farm. Some of them farmed goats (n=7) and cattle (n=6), with average numbers of 166 ± 84 and 116 ± 107 individuals, respectively. The size of the farm was closely significant correlated with the number of livestock farmed (Spearman's ρ: 0.490, $p = 0.064$). In reference to the location of the farms and proximity to protected areas, the distance to a protected area was not significant with the level of conflict (Spearman's ρ: 0.449, $p = 0.108$) or with the amount of sheep predated by carnivores (Spearman's ρ: 0.347, $p = 0.225$).

4.3.2. Carnivore conflict characteristics

Livestock losses

Respondents were asked to rank (from very rarely to very frequently) the main causes of livestock loss on their farms, and all of them considered carnivores as a ‘‘very frequent’’ or ‘‘frequent’’ livestock loss. The following causes were poor grazing and drought which were considered ‘‘occasional’’ or ‘‘frequent’’ losses as observed in Figure 9.

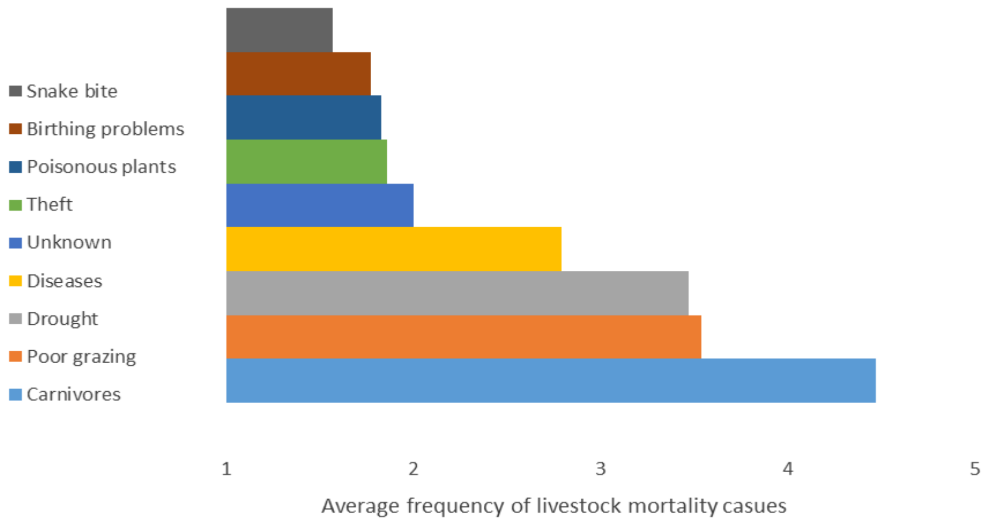

Figure 9. Mean frequency of livestock mortality causes estimated by the respondents, where 1 = ‘‘very rarely’’, 2 = ‘‘rarely’’, 3 = ‘‘occasionally’’, 4 = ‘‘frequent’’ and 5 = ‘‘very frequent’’.

To be more precise, farmers were asked separately about the numbers of livestock owned, losses to all causes and losses to carnivores. From the general stock, 4.2% (N=2) cattle, 8.4% (N=4) goat and 11.3% (N=10) sheep were lost to carnivores. While to all causes, 7.3% (N=2) cattle, 11.1% (N=4) goats, and 16.5% (N=10) sheep were lost.

To evaluate the approximate cost ($US) that carnivore losses had on farmers, the median number of livestock lost per farmer was calculated and an estimation was performed using the market value per individual (Table 5). For cattle, the median number turned out to be zero as only one farmer out of three had losses. For goats, as 12.5 individuals per farmer were estimated to be lost to carnivores, this amounted to $US 1,150 yearly. The biggest cost was due to sheep loss, as 30 individuals were lost yearly, accounting for $US 1,980.

Table 5. Number, type, and cost of livestock losses per farmer to all causes and to carnivores during 2019. Estimation losses ($US) are based on the median number of livestock losses.

	Median number of livestock losses to all causes per farmer	Median number of livestock losses to carnivores per farmer	Average cost of livestock individual ($US)	Estimation losses ($US) to carnivores per farmer
Cattle	7.5 (N=6)	0 (N=3)	201	0
Goats	20 (N=4)	12.5 (N=4)	92	1,150
Sheep	78.5 (N=10)	30 (N=10)	66	1,980

Level of conflict

The level of conflict differed significantly (χ^2 = 79.79, df = 28, p = 0.000) between the different carnivore species. Jackals were the leaders with all farmers arguing that they represented big or extreme conflict (Figure 10). Caracals were second in line with still high conflictive levels. Although baboons were not on the list for being primates, several farmers (n=6) add them as ‘‘other’’ conflictive species. Wild cats and Cape foxes were characterized by moderate conflict levels while leopards, honey badgers and brown hyaenas presented mild conflict values.

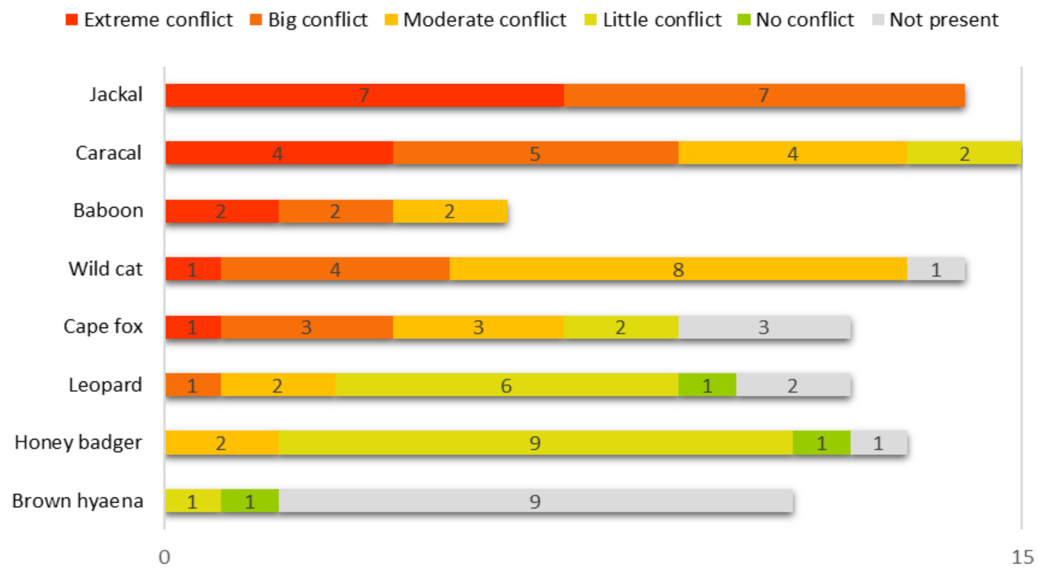

Figure 10. Level of conflict perceived by farmers for the different carnivore species.

The level of conflict was not correlated with the amount of sheep predated by carnivores (Spearman's ρ: 0.185, p = 0.508).

Attitudes towards carnivores

Attitudes towards carnivores were mainly negative throughout the contestants (Table 6). The majority (73.3%) answered that attacks on livestock could not be tolerated as they supposed a risk for business. The most voted solution was to remove all carnivores (60%) instead of improving the livestock management (33.3%). Only four farmers (26.7%) accounted for the ecological role carnivores play in ecosystems. No relationship was found between the four farmers that had a pro-ecological position and the level of conflict (Wald = 0.364, p = 0.546, β = 0.780).

Table 6. General attitudes towards carnivores expressed by the farmers.

		Count	Percentage based on respondents	Percentage based on answers
What do you think about carnivores?	Play an ecological role	4	26.7	7.7
	I want them removed and living in protected areas	8	53.3	15.4
	The solution to reduce losses is to remove all carnivores	9	60	17.3
	I can reduce losses by improving my management	5	33.3	9.6
	I like them on my farm	0	0	0
	Need to be protected	0	0	0
	We cannot tolerate attacks	11	73.3	21.2
	Total	15	100	100

Farmers were asked what were the situations in which they would perceive a carnivore problem. The same situations were proposed when asked at what moment they would take action and remove carnivores. More respondents agreed that there was a problem when several livestock were killed (n=12, 80%) in comparison to one individual killed (n=10, 66.7%). However, the same number (n=11, 78.6%) expressed the willingness to remove them no matter the number of livestock killed. A high percentage of farmers considered a problem when livestock came without calves or carnivore tracks were found (n=13, 86.7%). The smallest problem and less willingness to remove carnivores was given when game animals were killed (n=4, 26.7%). The perception and the action were tested to examine if the same farmers would perceive a problem and act accordingly to it. All answers with one exception, were significantly dependent (Table 7); meaning that there was little distinction made between the feeling of a problem and the willingness to remove carnivores. It is difficult to explain the non-dependent answer as two farmers saw a problem but not the necessity to remove the carnivore, and one did not see the problem but the willingness to remove it. In the same direction as these results, all farmers (N=14, 100%) tried to prevent attacks on livestock and believed that killing carnivores would prevent those attacks.

Table 7. Relationship between carnivore perception and the action to remove them. Dependency of the variables was measured with the chi-squared test. Statistical significances are shown with the p-values.

	When do you think there is a carnivore problem?	When do you remove carnivores?	Chi-squared test
When several livestock are killed	80%	78.6%	$\chi2$ = 4.03, df = 1, p = 0.045*
When one livestock is killed	66.7%	78.6%	$\chi2$ = 10.05, df = 1, p = 0.002*
When livestock come without calves	86.7%	85.7%	$\chi2$ = 0.32, df = 1, p = 0.571
When carnivore tracks are found	86.7%	85.7%	$\chi2$ = 4.43, df = 1, p = 0.035*
When carnivores are seen	73.3%	78.6%	$\chi2$ = 14.55, df = 1, p = 0.000*
When game is killed	26.7%	28.6%	$\chi2$ = 5.75, df = 1, p = 0.016*

Identifying attacks of carnivores

Farmers seemed to know which was the carnivore species responsible for the attacks when they were asked about it. All farmers (100%) said to be capable of identifying jackals (N=14), caracals (N=14) and wild cats (N=11) attacks. Eight out of nine (89%) knew how to identify cape fox attacks, three out of four (75%) leopard attacks and four out of five (80%) honey badger attacks. Regarding the brown hyaena, only one farmer answered arguing not knowing it. It seemed that farmers were more certain to identify the most conflicting carnivores as there was a high response level regarding the caracal and jackal; however, no relationship was found (Wald = 2,314, p = 0.128, β = 1,628), probably due to the very few 'no' responses and the high amount of blanks. When asked if the attacks were gathered at a specific time of the year, most responses (n=8, 80%) argued that attacks happened throughout the year. Only two farmers commented that jackals were somehow focused between September and November.

During the informal interviews, farmers shared some knowledge about the way of identifying the responsible carnivore species. Jackals used to tear sheep guts, felines would attack to the neck area, and honey badgers would go for the lambs' snout. It was also commented that wildcats would only attack newborn lambs.

Removing carnivores

All farmers (N=14, 100%) confessed that they tried to removed carnivores. The techniques most used were shooting (100% of farmers used it) and gin traps (92.9% did). Trap cages and dogs were still moderately used, while poison was the last used one (Table 8). Some techniques mentioned as ''other'' were night hunting, and the use of a gyrocopter in the biggest farm of all (500 km^2).

Table 8. Methods used to remove carnivores and the percentage of farmers using them

	Count (n)	Percentage based on respondents	Percentage based on answers
Shooting	14	100	21.9
Trap cage	9	64.3	14.1
Dogs	7	50	10.9
Poison	4	28.6	6.3
Gin traps	13	92.9	20.3
Other	4	28.6	6.3
Total (N)	14	100	100

Farmers were asked about the estimated number of carnivores present in their farms, the number of carnivores that were removed, and the feeling of the carnivore population trend since they owned the farm (i.e. increase, decrease or stayed the same).

No correlation was found (Spearman's ρ: 0.235, $p = 0.082$) between the estimated number of carnivores present and the numbers removed, meaning that farmers would remove carnivores independently of their numbers. The estimated number of carnivores present was tested for dependency with the level of conflict. For this, only the four most conflictive species were selected. No significant differences were present for the jackal ($\chi^2 = 5.04$, df = 4, $p = 0.283$), caracal ($\chi^2 = 16.28$, df = 12, $p = 0.178$), wild cat ($\chi^2 = 8.27$, df = 8, $p = 0.408$), or cape fox ($\chi^2 = 3.68$, df = 6, $p = 0.720$). The same procedure was performed testing now the removal of the four most conflictive species with the percentage of livestock predated. Jackals showed a statistically positive correlation (Spearman's ρ: 0.616, $p = 0.024$), meaning that farmers presenting higher predation rates would be removing more jackals. Caracals showed a positive relationship although no significant (Spearman's ρ: 0.504, $p = 0.095$), while wild cats and cape foxes showed a negative no significant correlation (Spearman's ρ: -0.162, $p = 0.615$; Spearman's ρ: -0.317, $p = 0.373$). Lastly, no significant relationship was found between farmers presenting a pro-ecological position and the number of carnivores removed (Wald = 0.787, $p = 0.375$, $\beta = -0.189$).

Table 9 shows the average estimated number of carnivores in farms and the average number of carnivores removed, together with the population trend. While the Cape fox and wild cat were the most abundant carnivores, the jackal was the most removed. There was a significant positive correlation between the level of conflict and the number of carnivores removed (Spearman's ρ: 0.498, $p = 0.000$), meaning that the bigger the conflict, the more carnivores farmers would remove. All respondents said to have on their farms jackals, caracals, wild cats, and cape foxes; in addition, all of them said to have removed jackals or caracals during the last year (Figure 11).

The population trend reported by the farmers (Table 9) seemed to be decreasing for all the species except for the leopard and brown hyaena. When removing leopards, farmers were asked if they knew that they were a vulnerable protected species and if they afterwards reported the death. Eleven farmers (78.6%) knew that the leopard was protected, but only two (14.3%) reported the removal.

Table 9. Carnivores' average and standard deviation presence estimation and removal during 2019. Number of carnivores removed are excluding farmers who did not have species on the farm. In addition, the percentage of species occurrence, respondents removing carnivores and the trend of carnivore population are shown.

	Respondents on which farms species occurred (%)	Average estimated number of carnivores within farms	Respondents removing carnivores (%)	Average number of carnivores removed per farmer	Respondents reporting an increase (%)	Respondents reporting a decrease (%)
Jackal	100 (n=14)	16.9 ± 7	100 (n=13)	11.54 ± 9.3	15.4	69.2
Caracal	100 (n=15)	13.6 ± 5.4	100 (n=12)	6.1 ± 6.4	38.5	53.9
Wild cat	100 (n=14)	17.9 ± 7.8	92 (n=11)	6.5 ± 4.6	11.1	66.7
Cape fox	100 (n=10)	20.5 ± 5.1	87.5 (n=7)	6.4 ± 6.2	10	80
Leopard	72.7 (n=8)	16.6 ± 5.5	20 (n=1)	0.6 ± 1.3	60	40
Honey badger	88.9 (n=8)	11.8 ± 2.3	40 (n=2)	3.2 ± 4.4	0	85.7
Brown hyaena	33.3 (n=2)	13 ± 0	0	0	50	0

Figure 11. Pictures taken in one of the farms showing a dead caracal (left) and jackal (right). The farmer argued the carcasses we left there to scare predators away.

Livestock management

Farmers used various methods to protect livestock and keep carnivores away. The most used one was electrical fencing (n=14, used by 93.3% of farmers), followed by kraals (n=7), dogs (n=5), and herders (n=4) (Figure 12). Seven farmers (46.7%) used only one method (electric fencing), and the rest eight used a combination of methods.

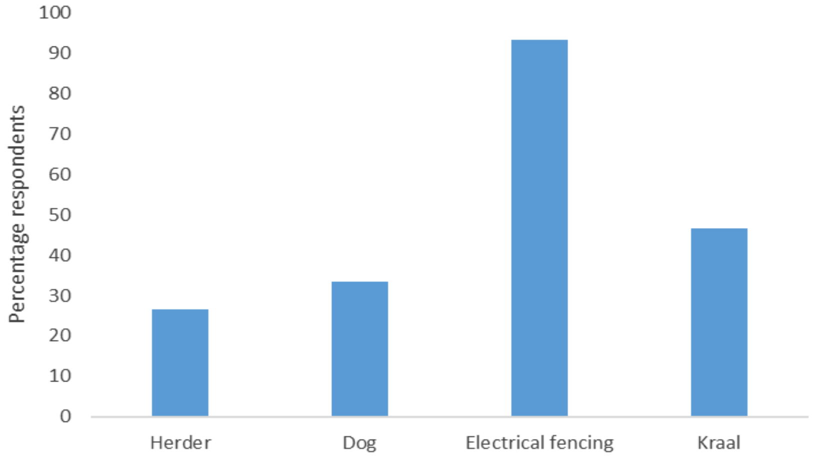

Figure 12. Percentage of farmers using the methods mentioned to protect their livestock

Independently, each technique was tested with the percentage of sheep lost to carnivores and the level of conflict. No statistical difference was found, although there was a negative relationship with the sheep killed (i.e. the presence of a method would be related with a lower percentage of sheep killed) and positive with the level of conflict. (Table 10).

Table 10. Binary logistic regression results testing the presence of different methods used to protect livestock with two variables.

	Percentage of sheep killed by carnivores	Attitudes (level of conflict)
Herder	Wald = 0.117, p = 0.733, β = -0.015	Wald = 0.314, p = 0.575, β = 0.121
Dog	Wald = 0.066, p = 0.797, β = -0.009	Wald = 0.191, p = 0.662, β = 0.093
Electrical fencing	Wald = 0.244, p = 0.621, β = -0.025	Wald = 0.001, p = 0.976, β = 0.013
Kraal	Wald = 0.068, p = 0.794, β = -0.009	Wald = 1,379, p = 0.240, β = 0.241

When asked about the effectiveness of the different methods, the data were quite similar compared to the methods used. The same number of farmers using herders (n=4) and electrical fencing (n=14) agreed with its effectiveness. From the farmers using dogs (n=5), four of them saw the method as effective and from the seven farmers using kraals, five of them did.

As electrical fencing was considered the most effective method and observing that almost all farmers used it, a division into two groups was performed: farmers who only had electrical fencing (n = 7), and farmers who had electrical fencing and one or more of the three methods mentioned (kraal, herder, or dog) (n = 7). This comparison was also based on the objective of the different methods: while fencing is used to keep carnivores outside the fenced area, if this barrier is broken and predators enter then the livestock defence depends exclusively on the other methods. These two groups were compared to the percentage of livestock predated by carnivores (Figure 13).

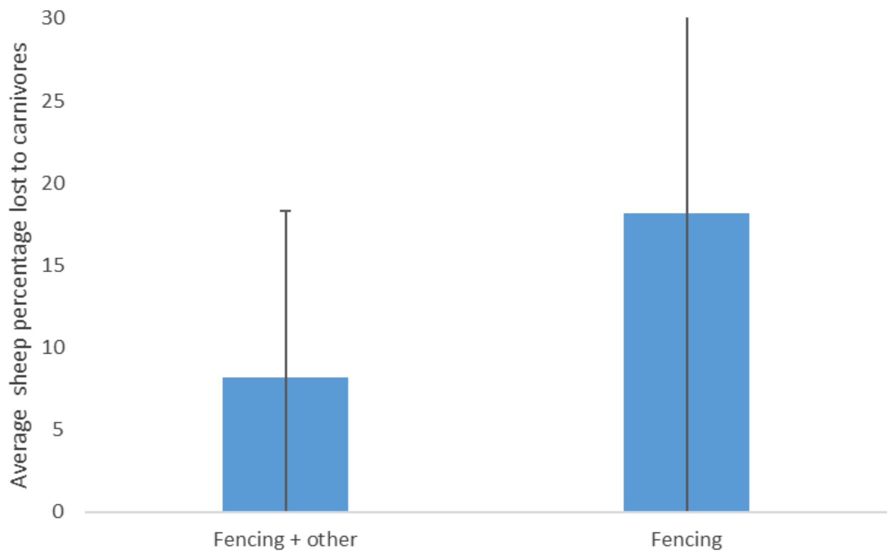

Figure 13. Average sheep percentage lost to carnivores in two different managed methods. On the right only electrical fencing present, and on the left fencing together with other methods such as herders, dogs, kraals or a combination of them.

The results show a difference in sheep percentage lost to carnivores but not enough to be statistically significant (H (3) = 0.36, p = 0.549). In addition, the standard error values are extremely high as the percentage of sheep lost varied greatly through the farmers.

Game use

Ten farmers (71.4%) performed hunting of game species within their farms -the most used income alternative to livestock-, while four of them did not (28.6%). A non-significant negative relationship was found between game use and level of conflict (Wald = 0.243, $p = 0.622$, $\beta = -0.660$), and positive between game use and the percentage of sheep predated by carnivores (Wald = 0.571, $p = 0.450$, $\beta = 0.046$).

Mitigating carnivore conflict

Farmers were asked about organizations dealing with carnivore problems. All of them (N=13, 100%) did not know any organization that would help to deal with carnivore problems and neither any of them (N=14, 100%) had ever received any compensation for livestock taken.

They were also asked if they wanted to receive help and if so, what type of help they would like to receive. Ten farmers (66.7%) wished to receive some type of help, while five did not (33.3%), not mentioning the reason behind it. The most voted type of help was compensation schemes (n=8, 66.7%), followed by having someone to remove the carnivores (n=5, 41.7%). The rest of offered help received less attention (n=2, 16.7%) (Figure 14).

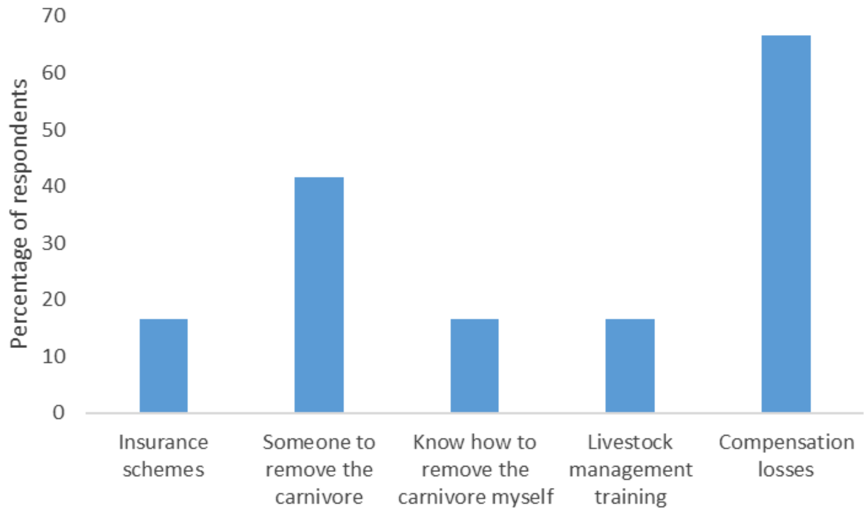

Figure 14. Type of help that farmers would like to receive to deal with carnivore problems.

When asked about the responsible person or organization that should solve carnivore problems, all farmers agreed they were themselves the responsible ones (N=14, 100%). Five farmers (35.7%) argued that the Ministry of Environment and

Tourism should be held responsible, and only 2 farmers (14.3%) mentioned the Ministry of Agriculture, the provincial government, or NGOs as responsible for the problem.

5. Discussion

5.1. Camera trap survey

As hypothesized, results show a clear difference in distribution between the farms and the wildlife reserve. From the six conflictive carnivore species, only two (wild cat and Cape fox) were found in the farms, showing that the methods used by farmers are effective in keeping some of the conflictive carnivore species away. From the two most conflictive species only jackals were observed in the wildlife reserve, converting the caracal into quite an elusive species as its presence was confirmed in the reserve in other habitats but was not observed in this study (Andres-Criado 2020). Neither of them could be found in the farms, however, it was proven they could access them and enter into conflict with farmers (Figure 11).

From the carnivores present in both areas, the abundance was lower inside the farms for the wild cat but did not seem to variate for the cape fox. These results coincide with a study performed in the neighbouring Northern Cape Province of South Africa, in which wild cats, caracals, and black-backed jackals' abundance was negatively affected on farms using predator control whereas cape fox abundance was positively affected (Blaum et al. 2009).

A particular distribution case was the yellow mongoose (*Cynictis penicillata*) as it was observed by camera traps and direct observation only in the farms. This species might have found farms more favourable due to the low abundance of predators such as jackals or caracals. This opens up an important field to study, in where animal communities can behave differently in farmlands where predator species are less abundant.

African wild cat

The occupancy results contrast with the camera trapping rate when comparing the two areas. While the occupancy is higher in the reserve, the CTR and thus detection probability present higher values in the farms. An important challenge in camera trap results is to account for the same individual appearing repeatedly in the same camera or even different cameras if the spacing is lower than the animals' home range (Kauffman et al. 2007). This is the case for most carnivores of this study -including the wild cat- as the methodology was shared with another survey (Andres-Criado 2020). If we observe the distribution of the events within the farms (Appendix 2a) we can see that they happen in closely placed camera traps (1.8 km), which probably were set in the core home range of the individual. This would explain the high CTR number as the same individual would pass through the cameras repeatedly. In contrast, the wildlife reserve shows sufficient separation between cameras to consider two different individuals. The occupancy results endorse this as there is a greater occupancy within the wildlife reserve, with yet an extremely low detection probability (p = 0.086), which would underestimate the occupancy result.

Relating these results with the management methods used by farmers, it is noticeable that the wild cat was only present on the farm that lacked guarding dogs. Although in the results there was no relationship found between the presence of dogs and the estimated presence of wild cats in farms, this last value refers to a perception of farmers, that can highly differ from reality. The presence of guarding dogs has been proved in several studies to lessen the conflict with carnivores (Rust et al. 2013; Whitehouse-Tedd et al. 2020); however, little is known about their effect on carnivores' occupancy. Only one study has addressed this relation until this date, where it was found that carnivore conflictive species would still inhabit farmlands guarded by dogs (Spencer et al. 2020). Yet this study only considered three species (black-backed jackals, leopards and brown hyaena), leaving the wild cat out of this study. Further investigation of guarding dogs' effect on smaller conflictive carnivores would be necessary.

Black-backed jackal

The most conflictive species was only observed in the wildlife reserve with a modelled occupancy close to one, being present in eight out of ten camera traps. The separation of the detected cameras and their home range make it possible the presence of several breeding pairs in the area. The reason for their absence in the farms is probably due to the electrical fencing, as it was, accordingly to farmers, the most effective method to keep jackals (and other carnivores) away from their farms.

Brown hyaena

It was only detected in the wildlife reserve, corresponding with other studies that detected a higher density in protected areas compared with agricultural lands (Thorn et al. 2011). Its presence on only three events resulted in a low CTR and low detectability (p = 0.03). Therefore, occupancy estimates need to be considered carefully as the detection probability is lower than 0.1 (Rovero et al. 2014). The modelled occupancy turned out to be almost one, occupying all the wildlife reserve area. This can be understood as brown hyaenas are animals with large home ranges (220-480 km^2) which cover more than the study area. The large home ranges and shared territoriality with members of the same clan make impossible the abundance estimation.

Caracal

Yet being the second most conflictive species, no presence was reported on the farms neither on the wildlife reserve. The methodology shared survey carried out during the same period and within the wildlife reserve found two caracal events in two different habitats: in shrublands and mountainous areas, identifying two different individuals (Andres-Criado 2020). However, whit this scarce information little conclusions can be drawn.

Cape fox

Cape foxes were present in both managed areas and presented the highest CTR values. Their occupancy accounted for 70-80% of the area and acknowledging their small home range (1-5 km^2) it can be considered the most abundant species. If compared the two areas, the occupancy was higher inside the farms, but the camera trapping rate was highest in the wildlife reserve and more uniformly distributed, which balances the abundance between the areas. When observing the distribution of events (Appendix 2d) and considering two closely events as triggered by the same individual, also a similar abundance estimation within the two areas can be predicted.

Honey badger

The honey badger results can be interpreted in a similar way compared to those of the brown hyaena. Similarly, only two events were observed in the wildlife reserve resulting in low CTR and detectability, but an occupancy close to one. The large home range of honey badgers (126-541 km^2) could explain again the occupancy of the whole study area but would make impossible an abundance estimator.

Leopard

Little can be inferred from the leopard with only a single detection in the wildlife reserve. However, a current research focusing on leopards in the study area observed higher abundance within the protected area when compared to the farms (unpublished, Viktor Neštický).

5.2. Questionnaires

Since the questionnaires of this study were based on a dissertation thesis performed in Namibian north-central farmlands (Schumann 2009), many answers were comparable to this study so that differences or similarities within the farmers could be drawn.

Attitudes and level of conflict

The level of conflict per species differed as some species were more problematic than others. These results go along with other studies performed in Namibia or South Africa that claim jackals and caracals as the most problematic carnivore species and most often implicated in predation (Thorn et al. 2012; Somers et al. 2018). Conflict studies with larger predators such as leopards and hyaenas are widely found in literature, however, little attention is given to smaller carnivores such as the wild cat and cape fox, which in this study were more problematic than the larger carnivores.

Contrary to some studies (Schumann 2009; Lindsey et al. 2013), there was no correlation found between sheep predated and the level of conflict. There was also no relationship between the number of individuals estimated per species and the conflict towards that species. This shows a hostility that does not depend on the number of individuals present and that is not related only to direct impact losses, but that is more based on a preconceived image of carnivores as species threatening their livestock. This type of conflict may be driven by a complexity of factors such as cultural beliefs, fear, or hostility from past experiences (Dickman 2010; Mkonyi et al. 2017). It is therefore more difficult to treat, as a reduction in livestock predation or carnivore numbers will not necessarily implicate a reduction of the conflict, but a complete change of mindset would be needed.

Attitudes were in general negative; none of the farmers liked carnivores in their farms or thought they should be protected. Only four farmers (26.7%) recognized the ecological role carnivores played in comparison to the 48% from the study performed in Namibian northern-central farmlands (Schumann 2009). Pro-ecological farmers did not differ from others in the level of conflict, but although not significant, there was a negative relationship with the number of carnivores being removed. This goes along with results from Schumann (2009) where pro-ecological farmers were less likely to want carnivores removed. Education schemes should be therefore implemented to improve knowledge about the ecological function of carnivores.

Livestock losses

Carnivores were pointed as the main cause of livestock mortality with 11.3% of the total sheep flock lost to them (8.6% in Schumann (2009) and 10.3% in Rust and Marker (2014)). If considering cattle and goat, average losses would lower to 8% since sheep were the most vulnerable species. However, this number is still over the average of other studies which losses round 1.4-2.8% in South Africa (Thorn et al. 2012; Thorn et al. 2013), 4.5% in Tanzania or 2.2% in Botswana (Holmern et al. 2007; Schiess-Meier et al. 2007). The estimation losses in $US if owing livestock would round 3,130 per person and annum, similarly to the US$ 3,461 observed in the study addressing the cost of carnivore presence in Namibia (Rust & Marker 2014). This supposes an important impact on households that will negatively affect how farmers perceive predators.

The distance to a protected area has been an influential variable determining the risk of predation and level of conflict in other studies (Gusset et al. 2009; Thorn et al. 2012), however, no relationship was found in this survey.

Results from this research -although no significant-, showed that the presence of game use was related to a lower level of conflict, but with a higher percentage of livestock predation. Farmers who benefit from game species might accept better the role that carnivores play in ecosystems as predators maintaining a healthy prey population. In addition, having another source of income and not depending solely on livestock production might influence in lowering of the conflict. On the other hand, farms maintaining game populations -and thus more prey species- can potentially attract more carnivores and produce higher predation events. Kamler et al. 2019 showed in their study that farms maintaining springboks would attract more jackals as it was their favourite prey. Instead, they suggested a switch to other ungulate species that were less preferred. This should be considered when implementing management of game species.

Identifying carnivores

It seemed that farmers were certain about the attacks of caracals and jackals as there was a high response rate of farmers acknowledging its identification; however, there was a low response rate when it came to admitting the unfamiliarity of other carnivores killing, probably because of lack of knowledge. It is very important to identify the species of carnivore responsible for the killing in order to perform proper management. Jackals and hyaenas are also known for being facultative scavengers and could be feeding on livestock that died due to other causes. This makes difficult the cause of death identification, therefore signs at a kill need to be carefully observed to relate it to depredation or scavenging (Linnell et al. 2012).

The species more abundant estimated by farmers was the Cape fox, followed by the wild cat, which can be supported by the camera trap results. However, studies need to use carefully the carnivore numbers estimated by farmers for they might shift from real abundance numbers, especially for elusive species (Caruso et al. 2017). An example in this study is the camera trap output which shows presence of cape foxes in the three farms, yet two farmers pointed out their absence. Not acknowledging their presence might attribute their attacks to other species or -more probable- show the little and rare damage that Cape foxes produce to livestock (Somers et al. 2018).

Removing carnivores

Accordingly to other studies and as hypothesized, farmers used methods to remove carnivores from their farms (Blaum et al. 2009; Schumann 2009; Thorn et al. 2012). Shooting and gin traps were the most used methods, and jackals by far the species with most individuals removed. When removing carnivores there was a statistically positive correlation between the level of conflict and the number of carnivores removed, meaning that the more conflictive the species, the more individuals would be removed. Accordingly, there was also a positive correlation (and statistically significant for the jackal) between the number of jackals and caracals removed and the percentage of sheep predated. Removal is then more focused on several target species, especially caracals and jackals which have suffered a population decline according to farmers since they own the farms, and will be more accentuated within farmers that suffered higher livestock losses due to carnivores.

There was a clear significant correlation between the perception of a carnivore problem and the willingness to remove them. Observing carnivore tracks was considered already the biggest problem together with missing calves. This demonstrates that farmers are willing to remove carnivores if they relate them to a problem, and shows little desire to share the same land with them. This becomes a problem as the persecution would start without the actual damage to livestock being produced.

Livestock management

The most used method and accordingly most effective was electrical fencing, which was used to keep carnivores outside farms. When testing each independent method with the sheep predated, although no significant relationship was found, a negative tendency was observed (i.e. using a method would be related with a decrease in the number of sheep predated). Similarly, a difference in sheep lost was observed when only fencing was used compared to fencing combined with other methods. Although being quite effective, fencing can present some flaws: poor management design, animals trespassing them by jumping or digging under it or interruption of the electricity due to a short circuit. If this is the only method used and predators cross it, livestock is completely unprotected. For this reason, it is important to include other methods such as herders, dogs, or kraals to drive carnivores away. This study could not test the effectiveness of the different methods in combination with fencing due to the low sample size. The large standard error presented in Figure 13 also shows that the sample may not closely represent the population. With a bigger sample size, the difference would likely have become significant. Many studies support these methods to reduce livestock predation and diminish the conflict (Ogada et al. 2003; Kamler et al. 2019; Khorozyan & Waltert 2021). Miller et al. (2016) reviewed the effectiveness of techniques for reducing livestock depredation and found that husbandry techniques focused on Canids and Felids would reduce depredation between 42 and 100%. In particular, effectiveness was 3-100% for guard dogs, 50-86% for night enclosures, 70% for human guards and 58-100% for electric fences.

Mitigating carnivore conflict

All farmers agreed it was their responsibility to solve carnivore problems, and 66.7% wished to receive some type of help. The most voted type of help requested (66.7%) was to receive financial compensation for livestock losses, an understandable approach regarding the high number of livestock predated. Although compensation losses are widely used, their efficiency has been questioned as it might not motivate farmers to properly look after their livestock. For this reason, compensation schemes should be combined with other methods like preventive husbandry or education.

This study shows that a better preventative husbandry could reduce predation on livestock. However, when farmers were asked about the type of help wanted, only two (16.7%) asked for livestock management training compared to five (41.7%) wanting someone to remove carnivores. This corresponds with the solutions expressed by farmers, in where 33.3% of them believed in livestock management to reduce losses but 60% expressed that the solution was to remove all carnivores from the farm. In Miller et al. (2016) study, removing carnivores resulted in 67-83% effectiveness in reducing livestock predation. While it is still a high percentage, it would not get as effective as the husbandry methods mentioned before and it would only be a short-term solution as other predators can re-established in the empty niches (Linnell et al. 1999). Farmers should be informed more about the benefits of livestock husbandry to change their idea of the solution to the problem from a lethal approach to the implementation of non-lethal techniques.

Nonetheless, lethal practices are unlikely to disappear. Taking into account the high amount of financial losses due to carnivore predation, these could be recuperated somehow if the farm implements trophy hunting activities. These could be focused on game animals and on the problematic predators themselves. A well-regulated removal of carnivores and game species would serve as an economic boost and would change the value that farmers place in carnivores, ultimately lowering the conflict and promoting carnivore conservation (Romanach et al. 2007; Lindsey et al. 2013). Trophy hunting has already been implemented in other Namibian livestock farms as an alternative source of revenue (McGranahan 2011); and compared to tourism, trophy hunting is a more viable option due to the lower abundance of wildlife and the isolation location of the area (Lindsey et al. 2006).

6. Conclusions

This study provided a better understanding of the general attitudes of farmers towards conflictive carnivore species in South-eastern Namibia. It also showed how different livestock husbandry methods used by farmers affected carnivore distribution and abundance.

The distribution of conflictive carnivores was more focalized within the wildlife reserve in comparison to the livestock farms. Black-backed jackals, brown hyaenas, honey badgers and leopards were only found in the reserve, whereas wild cats and cape foxes were found in both areas. From these last two species, wild cats' abundance appeared to be slightly higher in the reserve, while the cape foxes' abundance did not seem to differ. Methods used by farmers to protect livestock limited the distribution of carnivores and impacted their abundance.

Livestock farming was a very important source of income for our respondents, and economic losses were high enough to consider them drivers of the conflict; however, it seemed that the conflict was more driven by social factors than by livestock predation itself.

Attitudes towards carnivores were generally negative, and varied between different carnivore species, being jackals and caracals the most conflictive ones. The acknowledgement of a carnivore problem -such as encountering tracks- was sufficient to start with the removal of individuals. The most conflictive species were also the ones that were removed the most, and farmers that suffered most from predation ended persecuting more jackals. Farmers that viewed the ecological role of carnivores were most likely to remove fewer individuals; however, as only a few farmers acknowledge it, informing about the ecological benefit that carnivores have over the ecosystem is recommended.

Livestock losses due to predation could be reduced with preventative husbandry. It is recommended the use of electric fencing together with other methods such as herders, dogs, or enclosures to keep livestock during the nights. Although husbandry methods by themselves will unlikely solve the conflict, a reduction of predation to acceptable levels can lessen the pressure place on carnivores and lead to a final reduction of their removals. Compensation schemes should only be considered if these measures are carried out.

Finally, implementing game ranching on the farms together with trophy hunting of game and predators species can serve as an additional source of revenue and change the value that farmers place on carnivores, ultimately lowering the conflict and supporting wildlife conservation.

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Appendices

List of the Appendices:

Appendix 1: Questionnaires

Questionnaire farming-carnivore conflict

About the farm

1. Personal information

- Age:
- Gender: ☐ Male ☐ Female
- Role on the farm: ☐Owner ☐ Foreman ☐ Other

2. Farm information

- Name of the farm:
- Size of the farm (ha):
- Complete the table

Livestock you farm with	Numbers farmed (during year 2019)	Numbers sold (during year 2019)
Cattle		
Sheep		
Goat		
Others (_______)		

3. Select how important are the following sources of income in your farm

Sources of income	Very important	Important	Neutral	Unimportant	Very unimportant	Not occuring
Livestock	◯	◯	◯	◯	◯	◯
Crops	◯	◯	◯	◯	◯	◯
Game meat	◯	◯	◯	◯	◯	◯
Tourism	◯	◯	◯	◯	◯	◯
Trophy hunting	◯	◯	◯	◯	◯	◯
Other(_______)	◯	◯	◯	◯	◯	◯

4. Select how frequent are the causes of livestock mortality in your farm

Causes of mortality	Very frequently	Frequently	Occasionally	Rarely	Very Rarely	Never
Poisonous plants	◯	◯	◯	◯	◯	◯
Drought	◯	◯	◯	◯	◯	◯
Poor grazing	◯	◯	◯	◯	◯	◯
Birthing problems	◯	◯	◯	◯	◯	◯
Carnivores	◯	◯	◯	◯	◯	◯
Theft	◯	◯	◯	◯	◯	◯
Diseases	◯	◯	◯	◯	◯	◯
Snake bite	◯	◯	◯	◯	◯	◯
Unknown	◯	◯	◯	◯	◯	◯
Other(______)	◯	◯	◯	◯	◯	◯

5. Select how far is the closest protected area to your farm

- ☐ 0-5 km away
- ☐ 5-10 km away
- ☐ 10-15 km away
- ☐ 15-20 km away
- ☐ More than 20 km away

6. What type of habitat can be found in your farm? Select one or several answers

- ☐ Plain
- ☐ Mountain
- ☐ Hill
- ☐ Other (______)

About the carnivores

7. Select how conflictive is each of the following species

Animal	Extreme conflict	Big conflict	Moderate conflict	Little conflict	No conflict at all	Not present in my farm	I don't know
Leopard	◯	◯	◯	◯	◯	◯	◯
Brown hyena	◯	◯	◯	◯	◯	◯	◯
Spotted hyena	◯	◯	◯	◯	◯	◯	◯
Caracal	◯	◯	◯	◯	◯	◯	◯
Jackal	◯	◯	◯	◯	◯	◯	◯
Wild cat	◯	◯	◯	◯	◯	◯	◯
Serval	◯	◯	◯	◯	◯	◯	◯
Cheetah	◯	◯	◯	◯	◯	◯	◯
Lion	◯	◯	◯	◯	◯	◯	◯
Wild dog	◯	◯	◯	◯	◯	◯	◯
Honey badger	◯	◯	◯	◯	◯	◯	◯
Cape fox	◯	◯	◯	◯	◯	◯	◯
Other (______)	◯	◯	◯	◯	◯	◯	◯

8. When do you think there is a carnivore problem in your farm? Select one or several answers

- ☐ When several livestock are killed
- ☐ When one livestock is killed
- ☐ When the livestock comes home without their calves
- ☐ When carnivores' tracks are found
- ☐ When carnivores are seen
- ☐ When I find game killed
- ☐ I don't think they suppose a problem
- ☐ Other (______)

9. What do you think about carnivores? Select one or several answers

- ☐ They play an ecological role on the farm
- ☐ I want the carnivores removed off the farm and to live only in the protected areas
- ☐ The only way I can reduce livestock losses is to remove all carnivores from my farm
- ☐ I can reduce livestock losses by adjusting my livestock management
- ☐ I like having carnivores living on my farm
- ☐ Carnivores need to be protected
- ☐ We can't tolerate carnivores attacking the cattle because it supposes a risk for the business

10. Select the number you expect from the following carnivores to live close to your farm

Carnivore	**0**	**1 to 5**	**6 to 10**	**11 to 15**	**16 to 20**	**More than 20**	**Not present in my farm**	**I don't know**
Leopard	○	○	○	○	○	○	○	○
Jackal	○	○	○	○	○	○	○	○
Caracal	○	○	○	○	○	○	○	○
Brown hyena	○	○	○	○	○	○	○	○
Wild cat	○	○	○	○	○	○	○	○
Cape fox	○	○	○	○	○	○	○	○
Honey badger	○	○	○	○	○	○	○	○
***Other (_______)**	○	○	○	○	○	○	○	○

*please, write in column 'other' if you have conflict with other species not present in this table

11. Do you try to prevent carnivores' attacks on cattle?

☐ Yes

☐ No

12. Do you believe killing carnivores would prevent attacks on cattle?

☐ Yes

☐ No

13. Complete the table regarding livestock losses <u>in this year 2019</u>

Livestock	Numbers of livestock losses to <u>all causes</u>	Number of livestock losses <u>to carnivores</u>	Estimate cost of livestock losses to carnivores	Average number of livestock losses per attack event
Cattle				
Goat				
Sheep				
Others (______)				

14. Are the carnivore attacks concentrated in specific months of the year? If so when? Specify the species

-

15. Are you able to identify which species is responsible for attacking the livestock?

Carnivore	Yes	No	It doesn't attack my livestock
Leopard	○	○	○
Jackal	○	○	○
Caracal	○	○	○
Brown hyena	○	○	○
Wild cat	○	○	○
Cape fox	○	○	○
Honey badger	○	○	○
***Other (______)**	○	○	○

*please, write in column 'other' if you have conflict with other species not present in this table

16. At which point, would you try to take action and remove a carnivore?

Select one or several answers

- ☐ When several livestock are killed
- ☐ When one livestock is killed
- ☐ When the livestock comes home without their calves
- ☐ When carnivore tracks are found
- ☐ When carnivores are seen
- ☐ When I find game killed
- ☐ I wouldn't take action in any of them

17. Did you try to remove by yourself a carnivore?

- ☐ Yes
- ☐ No

If you marked yes, go to question 18 and 19

18. Select one or several techniques you used for removing carnivores

- ☐ Shooting
- ☐ Trap cages
- ☐ Dogs
- ☐ Poison
- ☐ Gin traps
- ☐ Other (______)

19. Select the number of the following carnivores that you removed <u>in this year 2019</u>

Carnivore	0	1 to 5	6 to 10	11 to 15	16 to 20	More than 20	Not present in my farm	I don't know
Leopard	◯	◯	◯	◯	◯	◯	◯	◯
Jackal	◯	◯	◯	◯	◯	◯	◯	◯
Caracal	◯	◯	◯	◯	◯	◯	◯	◯
Brown hyena	◯	◯	◯	◯	◯	◯	◯	◯
Wild cat	◯	◯	◯	◯	◯	◯	◯	◯
Cape fox	◯	◯	◯	◯	◯	◯	◯	◯
Honey badger	◯	◯	◯	◯	◯	◯	◯	◯
***Other (______)**	◯	◯	◯	◯	◯	◯	◯	◯

*please, write in column 'other' if you have conflict with other species not present in this table

20. Since you owned the farm, what has happened to the numbers of carnivores? Select

Carnivore	Increased a lot	Increased somewhat	Stayed the same	Decreased somewhat	Decreased a lot	Not present in my farm	I don't know
Leopard	◯	◯	◯	◯	◯	◯	◯
Jackal	◯	◯	◯	◯	◯	◯	◯
Caracal	◯	◯	◯	◯	◯	◯	◯
Brown hyena	◯	◯	◯	◯	◯	◯	◯
Wild cat	◯	◯	◯	◯	◯	◯	◯
Cape fox	◯	◯	◯	◯	◯	◯	◯
Honey badger	◯	◯	◯	◯	◯	◯	◯
***Other (______)**	◯	◯	◯	◯	◯	◯	◯

*please, write in column 'other' if you have conflict with other species not present in this table

21. Did you know that the leopard is a vulnerable protected species?

☐ Yes

☐ No

22. When removing leopards, do you report it to the ministry of environment and tourism (MET)?

☐ Yes

☐ No

☐ I never removed it

About the management

23. What kind of management do you use for avoiding the carnivores?
Select one or several answers

☐ Herder that goes with the livestock

☐ Dog

☐ Electric fencing

☐ Kraal for livestock during the nights

☐ Other (______)

24. Select which do you think are the most effective management method to avoid each of the following conflictive species. You can select one or several options for the same species

Carnivore	Herder	Dog	Electric fencing	Kraal	Other (_____)	Not present on my farm	I do not know how to avoid it	It is not a conflictive species
Leopard	◯	◯	◯	◯	◯	◯	◯	◯
Jackal	◯	◯	◯	◯	◯	◯	◯	◯
Caracal	◯	◯	◯	◯	◯	◯	◯	◯
Brown hyena	◯	◯	◯	◯	◯	◯	◯	◯
Wild cat	◯	◯	◯	◯	◯	◯	◯	◯
Cape fox	◯	◯	◯	◯	◯	◯	◯	◯
Honey badger	◯	◯	◯	◯	◯	◯	◯	◯
*Other (____)	◯	◯	◯	◯	◯	◯	◯	◯

*please, write in column 'other' if you have conflict with other species not present in this table

25. Game utilization→Is there any type of hunting of wild species in your farm?

☐ Yes

☐ No

If you answered yes, please specify which species ___________________________

____

26. Do you know any organization that helps or helped to deal with carnivore problems?

☐ Yes

☐ No

If you answered yes, please specify the name and type of assistance __________

____

27. Have you ever received any compensation for livestock taken?

☐ Yes

☐ No

If you answered yes, please specify the name of the organization and type of assistance ____

____

28. Would you like to receive help to solve the predation problem?

☐ Yes

☐ No

If you answered yes go to question 29. If you answered no, please justify ______

____

29. What kind of help would you like to receive for dealing with carnivore problems? Select with an X one or several answers

- ☐ Livestock insurance scheme for farmers (*owner takes out insurance against losses*)
- ☐ Someone to remove the animal for me
- ☐ Know how to remove carnivore by myself
- ☐ Training on livestock management to reduce losses to carnivores
- ☐ There should be compensation by losses from carnivores

30. Who do you think should be responsible for solving carnivore problem? Select with an X one or several answers

- ☐ I am responsible
- ☐ Ministry of Environment and Tourism
- ☐ Ministry of Agriculture
- ☐ Provincial government
- ☐ NGO (Non governmental organisation)

Appendix 2: Camera trap information sheets of conflictive carnivore species

a) African wild cat (*Felis silvestris cafra*)

Home range: 6-10 km^2

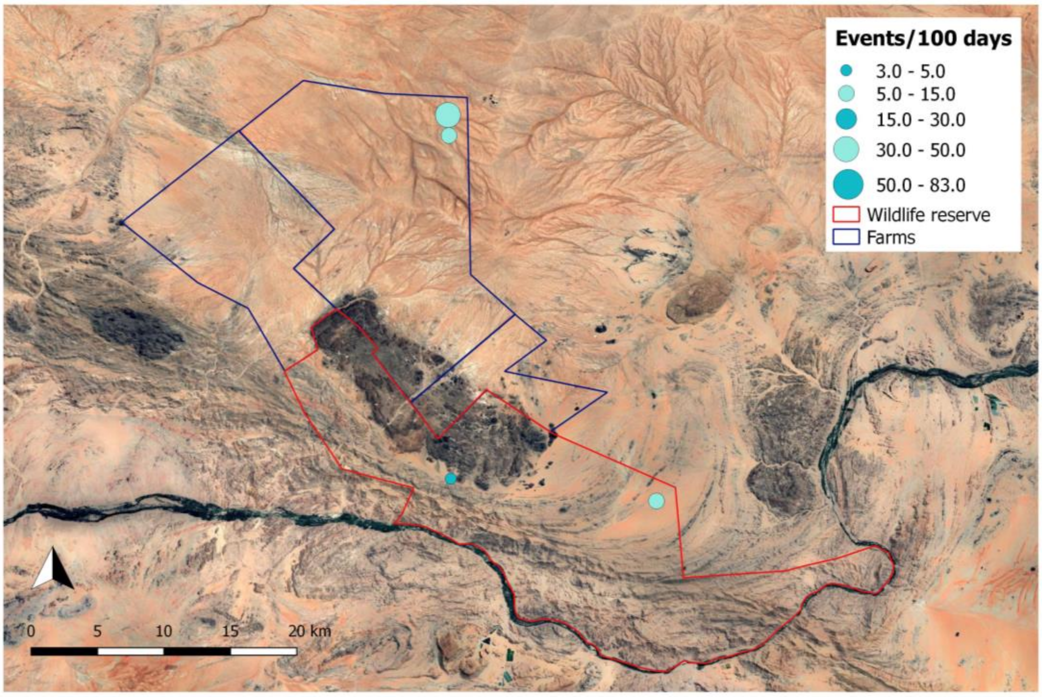
IUCN status: Least concern

Population trend: Decreasing

Survey results

	Wildlife reserve	Farms
Nº of cameras detected	2	2
Nº of detection events	3	14
CTR ± SE	1.07 ± 0.6	4.13 ± 1.32
Naïve occupancy	0.2	0.2
Modelled occupancy (ψ ± SE)	0.343 ± 0.296	0.2 ± 0.127
Detection probability (*P* ± SE)	0.086 ± 0.078	0.473 ± 0.115

Species distribution



b) Black-backed jackal (*Canis mesomelas*)

Home range: 3.5-25 km^2

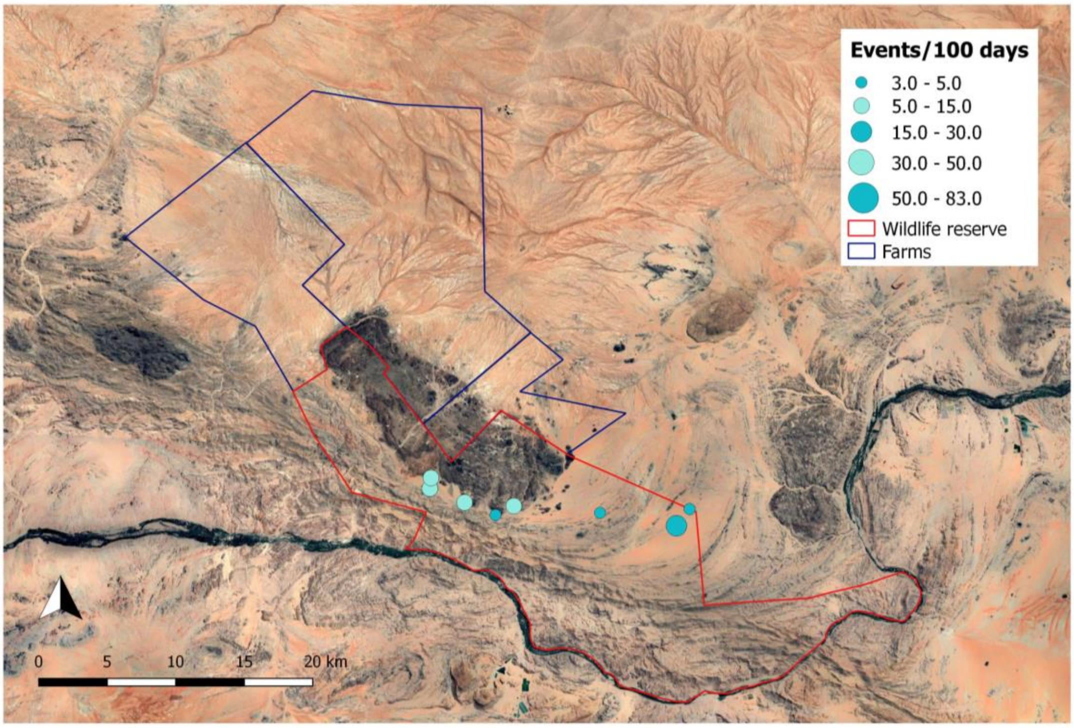
IUCN status: Least concern

Population trend: Stable

Survey results

	Wildlife reserve	Farms
Nº of cameras detected	8	0
Nº of detection events	17	0
CTR ± SE	5.78 ± 1.49	
Naïve occupancy	0.8	
Modelled occupancy (ψ ± SE)	0.985 ± 0.196	
Detection probability (*P* ± SE)	0.154 ± 0.048	

Species distribution



c) Brown hyaena (*Hyaena brunnea*)

Home range: 220-480 km^2

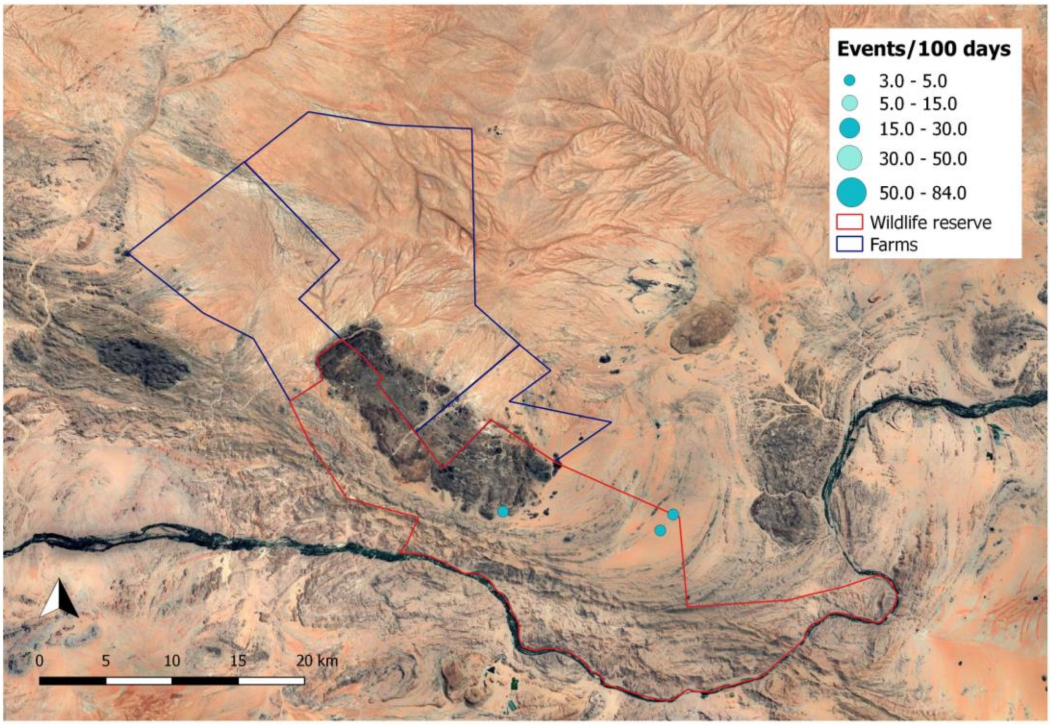
IUCN status: Near threatened

Population trend: Stable

Survey results

	Wildlife reserve	Farms
Nº of cameras detected	3	0
Nº of detection events	3	0
CTR ± SE	0.84 ± 0.59	
Naïve occupancy	0.3	
Modelled occupancy (ψ ± SE)	0.999 ± 0.044	
Detection probability (*P* ± SE)	0.03 ± 0.017	

Species distribution



d) Cape fox (*Vulpes chama*)

Home range: 1-5 km^2

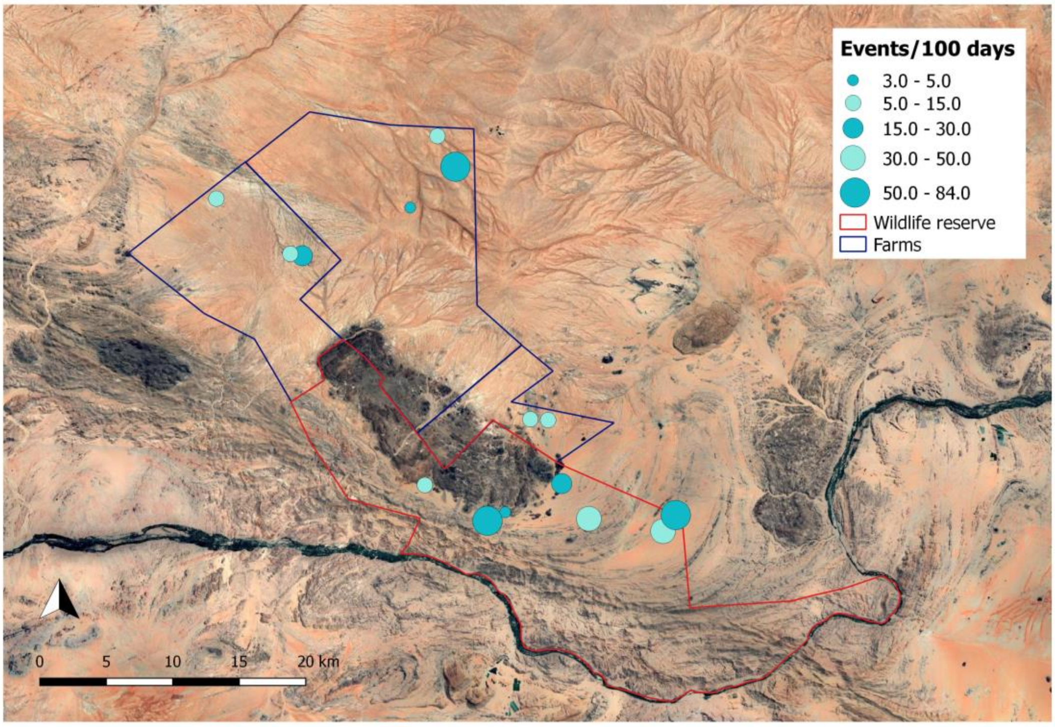
IUCN status: Least concern

Population trend: Stable

Survey results

	Wildlife reserve	Farms
Nº of cameras detected	7	8
Nº of detection events	79	51
CTR ± SE	26.13 ± 3.22	14.42 ± 2.83
Naïve occupancy	0.7	0.8
Modelled occupancy (ψ ± SE)	0.701 ± 0.145	0.819 ± 0.13
Detection probability (*P* ± SE)	0.485 ± 0.061	0.313 ± 0.055

Species distribution



e) Honey badger (*Mellivora capensis*)

Home range: 126-541 km^2

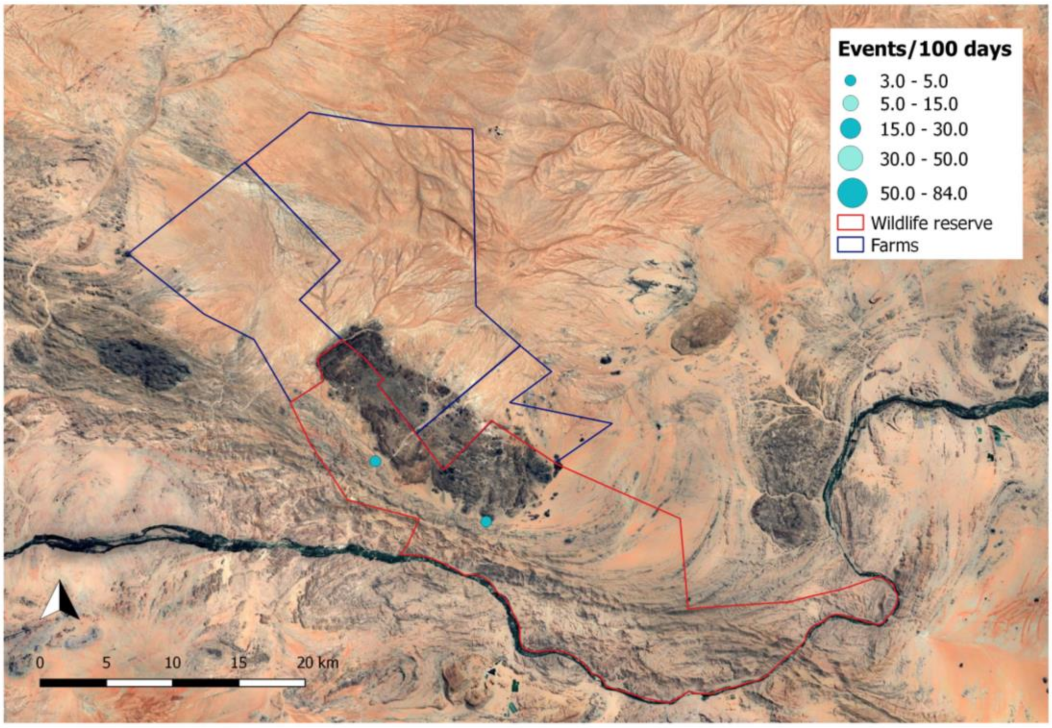
IUCN status: Least concern

Population trend: Decreasing

Survey results

	Wildlife reserve	Farms
Nº of cameras detected	2	0
Nº of detection events	2	0
CTR ± SE	0.75 ± 0.52	
Naïve occupancy	0.2	
Modelled occupancy (ψ ± SE)	0.998 ± 0.116	
Detection probability (*P* ± SE)	0.02 ± 0.014	

Species distribution



f) Leopard (*Panthera pardus*)

Home range: 180-230 km^2

IUCN status: Vulnerable

Population trend:

Survey results

	Wildlife reserve	Farms
Nº of cameras detected	1	0
Nº of detection events	1	0
CTR ± SE	0.36 ± 0.36	
Naïve occupancy	0.1	
Modelled occupancy (ψ ± SE)		
Detection probability (*P* ± SE)		

Species distribution