Human-Predator Conflict: The need for a new approach☆

E. du C. Luyt[a,1,*], A.J. Leslie[a,1], C. Hui[a,1], L.M. Marker[b,2]

[a] *Faculty of AgriSciences, Private Bag X1, 7602 Matieland, South Africa*
[b] *P.O. Box 1755, Otjiwarongo, Namibia*

Abstract

Although many methods have been suggested to mitigate human-predator conflict, it is still a worldwide and increasingly important problem, both for predator conservation and for livestock farming. In the past most solutions to this conflict have been either from an agricultural perspective or from a conservation perspective. However, because the goals of these two perspectives are seldom the same, there has been frustratingly little progress in preventing human-wildlife conflict. Here we review different published methods used worldwide to alleviate human-wildlife conflict, specifically conflict between livestock farmers and predators, the pros and cons of each method and the probable usefulness of the different methods to commercial livestock farmers in Namibia. We propose a more useful classification of methods than the usual lethal non-lethal dichotomy, comparing the various methods in terms of their long-term success and cost-effectiveness. We investigate the possible reasons for both failures and successes of the different methods. Lastly we propose that a new approach is needed if we want practical and sustainable solutions to our current human-wildlife conflicts.

Keywords: Human-wildife conflict, HWC, farmer-predator conflict, mitigating methods, Namibia, sustainability

1. Introduction

Human-wildlife conflict is a growing global problem (Messmer, 2000; Treves and Karanth, 2003b; Nyhus et al., 2005). This has implications both for agriculture and for conservation. Some authors consider the conflict to be primarily human-human conflict between agriculturalists and conservation ecologists, rather than between farmers and wildlife (Treves and Karanth, 2003a; Conradie and Piesse, 2013; Nattrass and Conradie, 2013). This imply that any solution to

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*Corresponding author
Email address: chavoux@gmail.com (E. du C. Luyt)
URL: http://www.cheetah.org (L.M. Marker)
[1] Stellenbosch University.
[2] Cheetah Conservation Fund.

the conflict should address both the agricultural perspective and the ecological perspective. Although using the general term "human-wildlife conflict" (HWC), this article really focus on carnivores and more specifically on predators. So the terms "human-carnivore conflict" (Khorozyan et al., 2015), "farmer-predator conflict" (Potgieter et al., 2016) will be used interchangeably, with the understanding that "human-wildlife conflict" as used here refers not only to carnivores in general, but specifically to conflict arising from depredation of livestock. We focused on commercial livestock farming in Namibia, but kept in mind that the same methods could work in other areas with similar circumstances and predators. Game farming and conflict caused by depredation of valuable game animals, is an important issue in Namibia, but differ too much from livestock farming to be considered here.

The greatest threat to large carnivores like mammalian carnivores and sharks, is direct killing by humans (e.g. Treves and Bruskotter, 2014), posing an even greater immediate threat than habitat destruction, especially in Africa (Ray et al., 2005). This includes killing of carnivores in retaliation for livestock depredation (Ogada et al., 2003). Large carnivores, often apex predators, need large home ranges or territories to sustain themselves, making them more vulnerable to extinction (Cardillo et al., 2004; Schipper et al., 2008). This is exemplified by the cheetah (*Acinonyx jubatus*), classified as vulnerable in the IUCN Red List (Durant et al., 2015). In Namibia, the country with the largest surviving population of cheetahs in the world (Durant et al., 2015), an estimated 90% of cheetahs are found on commercial livestock farms (private ranches) outside formally protective reserves (Marker, 2000; Marker et al., 2003a). Being shot on livestock farms is the major cause of death (Marker et al., 2010). In Southern Africa, most of the vulnerable leopard (*Panthera pardus*) habitat (Pitman, 2012; Stein et al., 2015) is found outside protected areas and the major threat to leopard survival is direct killing by people (Swanepoel et al., 2015). The same high percentage of habitat outside conserved areas is true for tigers, jaguars and snow leopards (Miquelle et al., 1999; Nowell & Jackson, 1996; quoted in Dickman et al., 2011). With farmers as the custodians of the majority of land in most countries of the world, the ultimate survival of many species are directly in the hands of farmers.

A telephone survey by Van Niekerk (2010) showed that livestock farmers in South Africa claimed a total annual loss of livestock directly to predators of R 1 390 453 062 (US$198 254 970 at 2010 exchange rates) (Bergman et al., 2013). These losses were unequally distributed with some districts and some farmers having much higher losses than the average. In addition to direct losses, Howery and DeLiberto (2004) make the point that behavioural changes in livestock because of predation risk, can cause a significant fall in production and reproduction rates. In the final instance, while everybody benefit from a functioning and biodiverse ecosystem, the cost of conserving large and sometimes dangerous animals is often borne disproportionately by farmers (Nyhus et al., 2005).

Predators fulfil an important role in functioning ecosystems, and their extermination has many unintended consequences, including trophic cascades (Ripple

Table 1: Some published Southern African livestock losses: Small and large livestock have been combined into a single equivalent Livestock Unit (LSU) value with 10 small livestock equivalent to one LSU. The price per kg of meat of small livestock can be up to twice that of cattle, but the ratio is not constant. The total number of livestock per farm is also not taken into account, which means that the *percentage* of livestock loss can be much more significant than the average number of LSU lost per annum would indicate. For the Marker et al., 2003b study, losses were divided into farmers who considered cheetahs as a problem and those who did not.

Study	Where	Period	Average loss/farm/year (FAO LSU)	Notes (Predators)
Conradie and Piesse (2013)	Ceres South district, SA	1979-1987	0.15 (range: 0.14-11.4, n=152)	Small livestock only (Caracal and Leopard)
Bailey and Conradie (2013)	Mossel Bay district, SA	1976-1981	0.094 (range: 0.0047-0.23, n=43)	Small livestock only (Caracal and Jackal)
Stein et al. (2010)	Waterberg, Namibia	2005-2006	1.75 (n=19)	Average annual loss: US$1370.00 (leopards)
Marker et al. (2003b)	North-Central Namibia	1991-1993	10.65 LSU | 4.55 LSU (n=241)	Large and small livestock combined (All)
Marker et al. (2003b)	North-Central Namibia	1993-1999	3.75 LSU | 1.81 LSU (n=241)	Large and small livestock combined (All)
Lindsey et al. (2013)	Wider Namibia	2010-2011?	1.82 (n=250)	Period not specified; US$2644.00 (leopards)
Van Niekerk (2010)	South Africa	2006-2007	5.83 LSU (n=1424)	Small livestock only (Caracal and Jackal)

et al., 2014) and extinctions (Estes et al., 2011; DeCesare et al., 2010), mesopredator release (Ritchie and Johnson, 2009), and savannah ecosystems becoming dominated by more thorny trees and shrubs (Ford et al., 2014). Ultimately, the persistence of ecosystem services (Reiss et al., 2009; CPW, 2014; Grace et al., 2016) and the stability of ecosystems as such, are dependent on its biodiversity (Cadotte et al., 2012; Hautier et al., 2015), and there is good reason to believe that predators are a major driver of high biodiversity (Terborgh, 2015). The leopard, an apex predator, has been considered as a reliable indicator of a healthy ecosystem, for example (Pitman, 2012). Extensive livestock farming is ultimately dependent on sustainable ecosystem services for its own survival as a viable economic activity (Bowe, 2000). For both the economic survival of livestock farmers and the persistence of relatively species-rich ecosystems on livestock farms (Kinnaird and O'Brien, 2012), it is important that solutions to farmer-predator conflict be found. Here we will 1) give a comprehensive overview of the different published methods used world-wide to mitigate farmer-predator conflict in terms of the limitations, known advantages and disadvantages of each method (Appendix A, Table 2 on page 7) discuss the possible reasons why, despite the availability of such a wide range of methods, HWC is still a major problem and 3) discuss a possible way forward.

2. Past approaches

Methods to mitigate human-wildlife conflict (HWC) vary in costs and effectiveness from doing nothing (free-range, extensive farming, zero cost and zero effectiveness) to feeding lots or barns (fed livestock, intensive farming, very high costs and almost 100% effective against predators). Mitigating methods have generally been classified as "lethal" or "non-lethal" (e.g. Daly et al., 2006; Shivik, 2004), implying that "lethal" methods are “bad” and that "non-lethal" methods are to be preferred. However, this classification runs into problems when a generally accepted "non-lethal" method, is shown to be lethal, and might even be approved by farmers because of this (e.g. Potgieter et al., 2016, 2013)! A "non-lethal" method like relocation of problem predators, sometimes not only fail to stop livestock depredation (Linnell et al., 1997), but can result in the death of either the newly introduced individual or it killing one of the current residents to take over its territory. This has a ripple effect in the receiving population with an increase in sexually selected infanticide (Keehner et al., 2015; Balme et al., 2009), similar to typical effects of trophy hunting. Moreover, because predators often travel for long distances, it can simply relocate the problem of livestock depredation to another area when the relocated predator leaves the conserved area to which it had been moved (Fischer and Lindenmayer, 2000; Weilenmann et al., 2010; Weise et al., 2015a,b). In effect, a so-called "non-lethal" method still result in the death of one one or more predators (Treves and Karanth, 2003a) leading some conservationists to conclude that it is sometimes better to simply kill problem individuals, rather than trying to relocate them (Stander, 1990; Ropiquet et al., 2015). On the other hand, some researchers have questioned the very existence of such "problem animals" (Linnell et al., 1999).

A bigger issue with the lethal = bad, non-lethal = good classification of HWC mitigation methods, is that sometimes a lethal method (e.g. trophy hunting an old male, that is past its reproductive prime, unable to hunt its natural prey and started to kill livestock) can be much less disruptive to the whole ecosystem than a non-lethal method (e.g. overgrazing and desertification due to kraaling, or translocation of a new individual into an existing stable population disrupting the whole territorial system, with more than one individuals killed or displaced). Therefore we propose that ecological disturbance (less = better) should be used to measure how appropriate a mitigation method is, rather than the common lethal / non-lethal classification.

Other alternative classifications for farmer-predator conflict mitigating techniques have been proposed. If the conflict is taken to its logical possible outcomes, there are only 3 possible endpoints:

1. The conflict continues, farmers win and the predators are extirpated on farmlands (the result reached in most of Europe and for top predators like lions and spotted hyaenas on most Southern African farms),
2. The conflict continues, predators win and livestock farming becomes impossible on the land, forcing a switch to other agricultural activities like tillage and crop production or non-agricultural land uses,
3. Farmers and predators make peace and somehow learn to co-exist. This could be achieved through either lethal or non-lethal conflict mitigating methods. The aim is a win-win situation for both livestock and predators.

Treves and Karanth (2003a) classified historic methods to reduce human carnivore conflict into three basic strategies:

1. Eradication, where the predators are extirpated on farmlands. This is the approach usually followed by governments in the past and advocated by many agricultural organizations (see Bergman et al., 2013; Rust, 2016). This equates to the first end-point of the conflict mentioned above (farmers win) if "successful". If unsuccessful, it could lead to the "predators win" endpoint.
2. Regulated harvest, where predators are hunted or killed, but not with the aim of eradication from farmlands. This is seldom effective (Treves and Karanth, 2003a) and is likely to worsen the long-term situation for both farmers and the ecosystem (Conradie and Piesse, 2013; Bailey and Conradie, 2013; Bothma, 2012; De Wet, 2002). This could result in either the predators "winning" or accidental eradication of predators (if unsuccessful) or co-existence (if successfully implemented).
3. Preservation, where non-lethal methods are used, leading to coexistence of farmers and predators on the land. These methods are often expensive or difficult to implement. This conservation strategy can result in either the second endpoint (farming become unsustainable) if unsuccessful, or the last endpoint (coexistence) if successful. Treves and Karanth (2003a)

> split non-lethal methods into either methods that change predator behaviour or methods that physically keep predators separate from livestock. Shivik (2004) subdivided non-lethal methods into 1) altering human behaviour, 2) altering husbandry or 3) altering predator behaviour. In practice, since all of these methods need to be implemented by humans, most likely the land-owners or farmers, and are presumably not currently being implemented, all of them depend on altering human behaviour. Madden and McQuinn (2014) classified methods used to address human-wildlife conflict into 5 groups: 1) physical/spatial (e.g. fences); 2) economic (e.g. incentive schemes); 3) technical (e.g. husbandry or farming methods); 4) legal (e.g. anti-poaching or quotas); 5) biological (e.g. using wild prey or predator behaviour).

Linnell et al. (1996) suggested that zoning should be used to determine which methods to apply, with 1) a conservation zone (preservation/ non-lethal methods only), 2) a buffer zone (including regulated harvest) and 3) the outside area (eradication/lethal methods only). They make the point that the choice of method depends also on the conservation status of the predators involved in the conflict. This zoning approach is less useful in the African context with most farmlands consisting of relatively intact habitat. We propose a threefold classification of mitigation methods for decision-making instead:

1. Preventative (pre-emptive) methods that attempt to prevent livestock depredation by carnivores. This could include both lethal (e.g. eradication of predators) and non-lethal methods (Shivik, 2004; Daly et al., 2006; Shivik, 2006).
2. Incentive (compensation/offset) methods (e.g.Stander et al., 1997; Mishra et al., 2003). These are methods that do not prevent or decrease livestock depredation, but in some way compensate farmers for the presence of predators on their land, to the extent that they would conserve rather than exterminate predators on their land. It can include both non-lethal methods (non-consumptive use) and lethal methods (e.g. trophy hunting of predators).
3. Reactive methods that only react to livestock depredation, rather than trying to prevent it. They differ in costs and effectiveness from methods in the previous two groups even when they appear similar (e.g. hunting of predators). They can be cheaper to implement (less often used) and cause less disturbance of farming ecosystem, because they are only used in reaction to actual livestock losses, but also carry a higher risk of livestock losses.

Because the "same method" can be used in more than one of the above three ways, with different costs and effectiveness, when evaluating them they should be considered as different methods. Pros (advantages, as used here), are positive aspects of the specific method that can theoretically be quantified while cons (disadvantages) are negative aspects that can also be quantified. Limitations measures the practicality of a method with a binary value of either true (practical for specific situations) or false (impractical in other circumstances). A full discussion of the pros, cons and limitations of each method can be found in the attached Appendix A.

The practicality of a certain conflict mitigating method is largely dependent on whether the farming enterprise is intensive or extensive. In general, a more intensive farming system attempt to maximize production or profit per hectare or per livestock unit while an extensive farming system attempt to minimize costs per hectare or livestock unit. The economic and ecological carrying capacity (Caughley, 1976), determined by both grazing and drinking water availability, are usually the most important external factors determining the possible intensity of the farming system, but distance to markets also play an important role. While not clear-cut categories,

- here intensive farming is considered as a system where the livestock owner sees or handles all his livestock at least once per day,
- a medium intensive system is where the livestock owner sees all his livestock at least once per week,
- a medium extensive system is where the farmer sees all his livestock at least once per month and
- extensive farming is where the farmer sees or handles all his livestock less than once per month.

Other factors that will typically impact the practicality of a certain method include the livestock species, predator species, labour, farm infrastructure, climate, topography and vegetation (habitat type), drinking water availability, existing management on neighbouring farms and the natural occurring wildlife on the farm.

Table 2: The various published methods used for farmer-predator conflict mitigation. Only the most important advantage, disadvantage and limitation of each method mentioned (See Appendix A for a fuller discussion).

1 Preventative methods				
1.1. Major ecological impact - Exterminating all predators on the farm				
Hunting to extermination	Beinart (1998)	Better veld utilization and productivity by livestock	Unlikely to succeed (needs 100% district-wide cooperation)	Better suited to transformed landscapes and not natural veld

Method	Reference	Main pro	Main con	Limitations
Dogs for extermination	Bergman et al. (2013)	Can be target-specific, especially against meso-predators	Can kill natural prey of predators and non-target species unless well trained	Requires good training that is time-consuming and not always effective
Eradication by poison bait	Linnell et al. (1996)	Easy to use	Ineffective with far-reaching negative ecological effects	Almost impossible to selectively kill predators
1.2. Intermediate ecological impact - Reducing predator numbers				
Hunting to reduce numbers	Conradie and Piesse (2013)	Extremely cheap and relatively easy	Can increase livestock depredation	Few limitations, counter-productive for some predators
Trapping and killing	McManus et al. (2014)	Relatively cheap and some traps can be selective	Relatively ineffective and can be very unselective	Need to be checked regularly: impossible on large farms with small labour force
1.3. Minor ecological impact - Allow predator numbers to stabilize				
Herding	Ogada et al. (2003)	Very effective	No grazing at night: Lower livestock productivity	Availability of reliable herders
Patrolling scaring predators	Stone et al. (2008)	Well suited to extensive farming	Not very effective when predators hunt at night	Need terrain fit for horses and horse-riding equipment
Kraaling at night	Woodroffe et al. (2007)	Proven effective at high predator densities (combined with LGDs or herding)	Trampling of veld around kraal	Impractical for extensive farming with multiple herds

Method	Reference	Main pro	Main con	Limitations
Kraaling young full-time	Marker et al. (1996)	Effective at high depredation levels	Labour-intensive; trampling	Require specific livestock breeding season; not extensive farming
Carnivore-proof fencing	Beinart (1998)	Only method ever partly effective in eradicating jackal	Expensive and double labour costs to maintain	Ineffective against felines, limited by camp size & terrain;
Electric fencing	Paige (2015)	Only fencing able to keep out all predators	Very expensive to put up and maintain	Too expensive for extensive farming with large camps
Calving/lambing camps	Linnell et al. (1996)	Combines well with many other management practices	Danger of trampling if not well managed	Unsuited to low stocking rates (extensive farming)
Static repellents	Shivik et al. (2003)	Easy to set up and low maintenance and labour	Temporary solution only, as predators habituate to them	Only suited for lambing seasons and small camps
Projectile repellents	Shivik (2006)	Effective non-lethal method to protect people like herders	Repellent associated with people and not livestock or area	Unsuited for predators hunting by night
Repellent collars	Linnell et al. (1999)	Distinguish livestock from natural prey, effective for longer in combination	Labour-intensive and high-tech versions expensive	Require natural prey to be available; not for extensive farming
Protective collars	Smuts (2008)	More cost-effective than trapping or hunting	Fairly labour-intensive	Less effective against non-felid predators changing their attack method; natural prey required

Method	Reference	Main pro	Main con	Limitations
Conditioned Taste Aversion	Forthman (2000)	Inexpensive and safe (*contra* poison)	Misapplication can increase depredation	Useless against predators that never scavenge; requires carcass removal
Chemical repellents	Hunt (1984)	No predator learning required	Labour-intensive and ineffective	Unsuitable for extensive farming
Natural repellents	Holmes and Holmes (2006)	Remain permanently effective	Need source of predator scat	Incompatible with lethal methods
Increase natural prey	Marker et al. (1996)	Costs almost nothing and combines well with other methods	Reintroduction expensive and slow when necessary	Needs natural habitat with wildlife densities above threshold
Livestock Guarding Dogs	Hansen (2005)	Effective and cheaper than herder	Year training by herder required	Can protect maximum of 200 small livestock
Guard donkeys	Linnell et al. (1996)	Cheap and fast (no training)	Less effective than LGDs	Ineffective against larger predators (leopards); require breeding seasons
Guard Llamas/Alpacas	Linnell et al. (1996)	Stronger bonding with livestock than donkeys	Scarce and expensive in Africa	Probably only effective against smaller predators (caracal & jackal)
Protection cattle	Linnell et al. (1996)	Works well combined with holistic management	Bonding takes time (and feed in small camps)	Ineffective against predators that attack cattle
Avoid depredation hotspots	Miller et al. (2015)	Sustainable, inexpensive and easy to implement	Known depredation hotspots need to be known (and mapped)	Not suitable for farms where all of the habitat is high-risk

Method	Reference	Main pro	Main con	Limitations
GPS collar predators	Personal observation	Almost no ecological impact	GPS collars currently very expensive	Not practical for smaller predators in high densities
Seasonal breeding	Shivik (2004)	Easy and inexpensive	Risk of lower livestock productivity	Only practical where there are seasonal depredation peaks
Changing livestock	Hoogesteijn and Hoogesteijn (2010)	Might be only option in very extensive farming system	New livestock breed or species might be less profitable	Not an option for stud farmers; options restricted by range
Farming with weaners only	Personal observation	Easy and relatively effective	No breeding selection possible	Still enough other farmers to produce the weaners
Horned cattle	Hoogesteijn and Hoogesteijn (2010)	Very easy and inexpensive to implement on extensive farms	Dangerous to handle and can hurt each other	Not suitable when marketing to feeding lots
Large herds holistic grazing	Bingham (1997)	Can improving range-land	Livestock management more complicated and risk of lower productivity and trampling	Not good fit in combination with lethal methods and some livestock breeds
Sterilize breeding alphas	Shivik (2006)	Effective when predation is due to feeding of predator young	Difficult and expensive	Not good option with scarce or threatened predators
2 Compensatory methods				
Trophy hunting of predators	Treves (2009)	Likely to change farmer attitude towards predators	Can have negative ecological population effects (e.g. SSI)	Income from trophies need to surpass livestock losses

Method	Reference	Main pro	Main con	Limitations
Direct loss compensation	Montag (2003)	Only co-existence option in areas without natural prey	Unintended consequences like perverse incentive not to protect livestock	Sustainable funding source and large-scale cooperation required
Insurance schemes	Nyhus et al. (2005)	Not dependent on NGO or government	Verification of predator kills difficult	Lack of predation risk assessment by insurance companies
Compensation for predators	Mishra et al. (2003)	No perverse incentives	Verification of predator numbers difficult	Large-scale cooperation required
Ecotourism	McGranahan (2011)	Can increase farming income	Tourism can habituate predators to humans	Unrealistic for remote farms in monotonous landscape
3 Reactive methods				
Killing a "problem animal"	Jaeger (2004)	Selective and less expensive than extermination	Can be ineffective or increase subsequent losses	Might be impossible on large and extensive farms
Translocation of predator	Weilenmann et al. (2010)	Can mitigate conflict and improve survival of threatened predator species	Ineffective if there is no single "problem individual" predator	Limited destination habitat available
Poisonous livestock collar	Linnell et al. (1996)	Selective and satisfaction of killing responsible animal	Sacrifice one livestock unit to kill one predator	Danger of poison, including possible ecological ripple effects

3. Why have past attempts at reducing HWC so often failed?

Despite the fact that various manuals with different possible solutions to human-wildlife conflict are widely available (e.g. Linnell et al., 1996; Shivik et al., 2003; Schumann, 2004; Shivik, 2004; Daly et al., 2006; Shivik, 2006; Smuts,

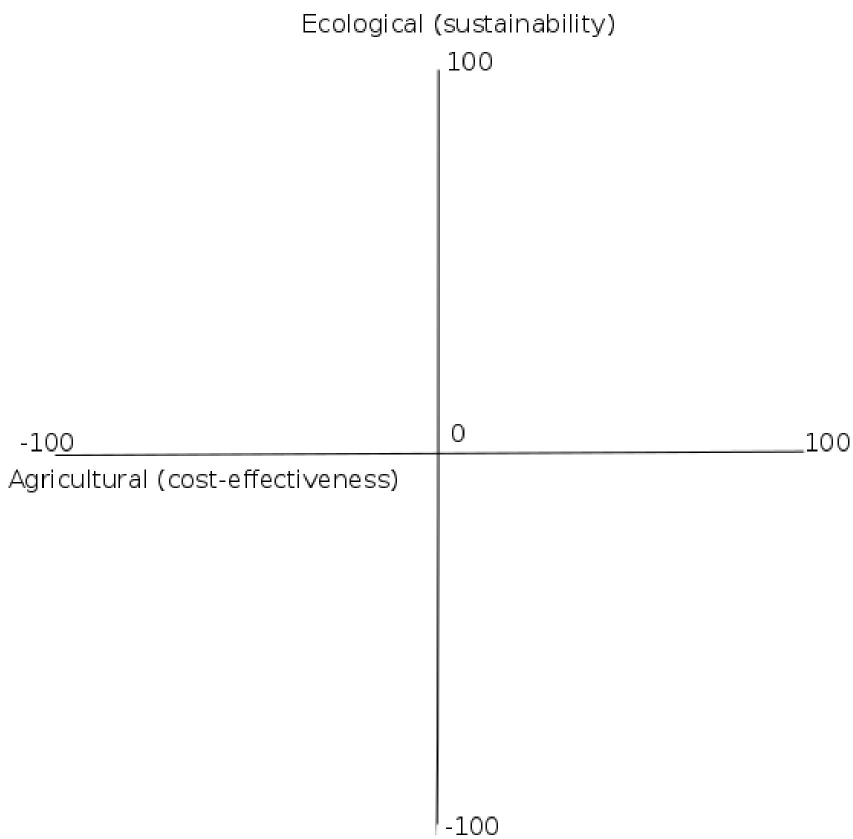

Figure 1: Advantages (0 - 100) and disadvantages (-100 - 0) of the different methods can conceptually be plotted on a scatter-plot with the agricultural cost-effectiveness and ecological sustainability as the two axes. Agricultural cost-effectiveness is defined as the survival rate (reciprocal of depredation loss) of livestock offspring per cost unit and ecological sustainability is a measurement of the ecological impact (assuming that less disturbance leads to higher biodiversity and sustainability).

2008; Stone et al., 2008; Chardonnet et al., 2010; Van Bommel, 2010; Begg and Kushnir, 2013; Paige, 2015), it is still a growing problem (Messmer, 2000; Hoogesteijn and Hoogesteijn, 2010). Nattrass and Conradie (2013) showed that livestock farmers and conservationists approach the problem of farmer-jackal conflict from two opposite starting points (narratives). Livestock farmers generally want to maximize production or profits per hectare of land and minimize their risk. Environmentalists generally want to maximize biodiversity. However, both groups share the following aims: 1) minimize conflict, 2) minimize cost, and 3) maximize sustainability. Since greater biodiversity also leads to greater sustainability (Cadotte et al., 2012), this means that in reality farmers and conservationists share all their aims, except for the two agricultural aims (maximizing production and minimizing livelihood risk). One would therefore expect that the two groups should be natural allies, with ranchers (livestock farmers) considered as partners in conservation rather than opponents (Hoogesteijn and Hoogesteijn, 2010). In reality, this seldom happens. The final managers and implementers of any method used to reduce HWC are the farmers themselves (Yoder, 2000). The current increase in cheetah numbers in Namibia (Marker et al., 2007; Purchase et al., 2007) can be directly ascribed to an increase in tolerance of cheetahs by farmers (Marker et al., 2003b). And yet, conflict with farmers also remain the main threat to the long-term survival of Namibian cheetahs (Durant et al., 2015). This highlights the fact that farmers are not a homogeneous group (Rust, 2016).

A number of different surveys have shown that greater perceived depredation livestock losses correlates with more predators being killed and more negative attitudes towards predators (Ogada et al., 2003; Marker et al., 2003b; Shivik et al., 2003; Lindsey et al., 2013; Rust and Marker, 2013; Dickman et al., 2014). However, this was often not the most important predictor of farmer tolerance of predators. Other studies have shown that in some cases the actual number of livestock losses to predators have little influence on farmer attitudes (Babrgir et al., 2015; Thorn et al., 2012, 2015) and compensation for losses do little to change livestock owners' attitudes (Montag, 2003; Naughton-Treves et al., 2003; Madden and McQuinn, 2014). But why? One possible explanation is that the risk of depredation losses can influence the attitude of a livestock owner just as much or even more than actual losses. We suggest two main reasons why the conflict continue:

3.1. Agricultural and ecological aspects not considered in combination

With a few exceptions (e.g. McManus et al., 2014), most published methods to mitigate HWC have been either from an agricultural perspective only, with little regard for the sustainability or ecological effect of the methods (Bergman et al., 2013; Shelton, 2004) or from an ecological conservation point of view, with little regard for or mention of the relative cost-effectiveness and actual practicality of the methods (CapeNature, Downloaded: 2016/09/15; Daly et al., 2006; Smuts, 2008). Even when the cost-effectiveness of the individual methods is considered, there is little consideration of the fact that methods that work well on some farms, will often fail in different agricultural circumstances.

A number of researchers have mentioned that predation losses does not seem to be uniformly distributed, even within the same district (Conradie and Piesse, 2013), and some farmers might have extremely high depredation losses, while the majority have relatively few losses (Van Niekerk, 2010). This appears to be an international feature of farmer-predator conflict, with similar reports for example, from Slovakia (Rigg et al., 2011) and the USA (Shelton, 2004). Different levels of depredation also imply that different management decisions and different anti-predation methods are required. Snow (2009) made the point that a full system-based approach is more likely to find the links of cause and effect than considering HWC in isolation.

3.2. Social aspects not adequately taken into account

A number of researchers have made the point that a lot of the conflict is really between different groups of people rather than between people and wildlife (Montag, 2003; Treves and Karanth, 2003a; Conradie and Piesse, 2013). Madden and McQuinn (2014) showed that material, visible manifestations of human-wildlife conflict are often rooted in less visible, more complex social conflicts between people and groups. This also explains why cultural and social aspects often have a greater influence on farmer attitude towards predators than actual livestock losses (Thorn et al., 2012, 2015) and require the use of conflict transformation tools to help solve these underlying, complex social conflicts (Madden and McQuinn, 2014). Where farmers feel excluded from the decision-making process about predators that will ultimately influence their livelihoods, the situation often deteriorates into one where farmers "shoot, shovel and shut up" (Hoogesteijn and Hoogesteijn, 2010; various Namibian farmers, personal communication). It is therefore not enough to know what method is most likely to succeed; unless farmers are empowered to make the decision for themselves using relevant knowledge, the uptake of better methods for preventing farmer-predator conflict will probably remain low because of the various social issues. Montag (2003) mentions that "much of the conflict is around the control of landowner land, government intervention, and private land rights", also hinted at by Rust et al. (2016) and Rust (2016). Madden and McQuinn (2014) mentions that conservationists and governments often resist giving up decision-making control, because they already have the law on their side or they may fear what will happen when stakeholders who seem less committed, or even antagonistic to conservation objectives, are given a legitimate voice in decision-making. However, in practice, working together is much more likely to result in win-win solutions (sustainable coexistence). It is thus interesting that almost all compensation schemes that had some level of success, were those in which the livestock owners participated actively in the decision-making process (Stander et al., 1997; Lukarevsky, 2003; Mishra et al., 2003) and thus shared ownership of the final solutions.

4. How to improve on past failures to resolve human-wildlife conflict?

Shivik (2006) opined that future methods "need to emerge from a mix of biology, sociology, and technology". It is well known that there is no silver bullet for human-wildlife conflict (Linnell et al., 1996). Except for permanently keeping all livestock in a barn and feeding them, no method is 100% effective in preventing livestock depredation losses. The aim should be to find the most cost-effective and sustainable method or combination of methods that fit the situation on a specific farm. One tool that potentially offers a way out of the current impasse, is the use of a Decision Support System (DSS) (Keen, 1980; Sprague, 1980) based on a Bayesian Probabilistic Graphical Model (PGM) (Koller and Friedman, 2005). It addresses the two main reasons why past human-carnivore conflict mitigation approaches still fail to reduce the conflict as follows:

1. Current methods often approach the conflict from either an ecological, conservationist viewpoint only or from an agricultural, short-term economic viewpoint only. Conservationists therefore frequently advise farmers to use eco-friendly methods that are impractical or not economically viable. Agriculturalists, on the other hand, often advise methods that appear to give short-term results, but are not sustainable in the long run and might actually aggravate the situation. This can be addressed by combining the two aspects, short-term cost-effectiveness and long-term sustainability, into a single PGM.
2. They usually only directly address the human-predator conflict itself and only recently started taking into account the social aspects of human-human conflict. But even so, the focus is often on social aspects of the conflict that might at best be a contributing factor (e.g. Rust et al., 2016) while ignoring the deeper levels of conflict between the ecological and the agricultural basic starting points which might be the most important reason why farmers are unwilling to risk or trust in "new" methods. Farmers themselves often feel left out and not well represented as partners in predator management decisions and advice (e.g. Bergman et al., 2013 when commenting on Daly et al., 2006). The importance of farmers as full partners in predator conservation on farmlands, and the final implementers of any HWC mitigating methods, as well as having to personally bear the brunt of all costs and risks, can be at least partially implemented by providing them with a Decision Support System. Farmers associations and agricultural unions using the DSS are then put in the situation where they can share ownership of ecologically sound solutions to human-wildlife conflict (*cf* Lukarevsky, 2003).
3. Past approaches very seldom (if ever) take cognisance of the differences between individual farms and farmers with regards to both ecological and agricultural aspects of the situation. The approach is often that of "one size fits all". The probabilistic model (PGM) can use the situation on an individual farm as the input (given observations) by which to calculate the most cost-effective and sustainable solutions for that farm.

4. Conservationists in particular are often guilty of not spelling out the known drawbacks and limitations of proposed solutions to livestock depredation and HWC, thereby creating unrealistic expectations (see for example Smuts, 2008; Daly et al., 2006). When farmers run into these, often unexpected, issues, they can become discouraged and return to their known and trusted (even if not very effective) "traditional" and unsustainable management practices. Not only do they personally abandon any of the possibly more effective methods, but typically they also spread the word that a certain method "did not work for me", discouraging other farmers from attempting it as well (Shivik et al., 2003). It is thus important that the advantages, disadvantages and limitations of the various methods available to a farmer should be known up-front before he commits himself to implementing it on his farm. Not only the ignorance of limitations, but also the incorrect implementation of methods can end in failure, with the same negative end result. The most important known disadvantages and limitations of the various methods are found in Appendix A and should be included in any results given by the DSS.
5. Rust (2016) found that the single most popular method for mitigating HWC was conservation education and husbandry training to reduce livestock depredation. Both farmers and behavioural ecologists still have great gaps in our knowledge of predator behaviour outside protected areas (Balme et al., 2014). As farms have become larger in order to remain economically viable and farming methods are often more extensive than they used to be (Nattrass and Conradie, 2013), farmers often also know surprisingly little about the behaviour of their own livestock (especially their anti-predator behaviour). This lack of knowledge can result in basic mistakes being made (like de-horning of all cattle), leading to unnecessary livestock losses. The lack of significant effect by any other method except the numbers of wildlife on farms in Namibia found by Marker et al. (1996), might be confirmation of the need for knowledge, showing that the implementation of the protection measures is possibly more important than which method is used. These implementation details can be included as part of an DSS, or training in the use of the DSS can include training in general on predator behaviour and HWC.
6. While often making the mistake of offering a "one size fits all" solution to farmers for their livestock depredation problems, the opposite mistake is made as well when scientists simply suggest a whole range of possible (usually non-lethal) methods for farmers to use (Shivik, 2004; Daly et al., 2006; Shivik, 2006; Smuts, 2008; Stone et al., 2008; Chardonnet et al., 2010), without giving them any comparative guidance on the effectiveness, costs and limitations of the different methods. This makes it just as difficult, if not impossible, for a farmer to choose the most appropriate method(s) for his particular farm and circumstances. This issue is addressed directly by the DSS selecting only a small number (e.g. three) of the ¨best¨ conflict mitigating methods, based on the input of the specific farmer. A choice of three methods, when the reason for choosing them as well as their ad-

vantages and disadvantages are explicitly stated, is much easier to make than choosing between six or more different methods without the required information for making a choice.

7. Because farming is inherently risky, farmers tend to be risk-averse and to keep doing what they know. However, circumstances have changed and keep on changing (e.g. climate change, market fluctuations, government support). Affordable and effective methods of the past, are no longer affordable or effective. By making these changes explicit, the PGM can help farmers realize why their familiar methods are no longer cost-effective and why other alternatives might be better.
8. One of the most important aspects of applying any predation-prevention method, is the good record keeping of the current situation on the farm (Stone et al., 2008). Knowing how much livestock is lost to predators, where most depredation happens in the farm and which predators are responsible, is basic knowledge that is required in order to make good management decisions. Hoogesteijn and Hoogesteijn (2010) actually list it as a preventative method by itself. A good computer system (e.g. a DSS) is fast becoming indispensable.
9. Because a DSS does not take the decision-making process out of the hand of farmers, and because it is not a person "telling the farmer what to do on his own farm", at least part of the common underlying distrust between conservation scientists and farmers because of past bad experiences, is avoided (Axel Rothauge 2014, personal communication). If the DSS is written in order to be transparent with regards to the algorithms and data it uses, it makes it easier to trust it.
10. If the DSS is written as open source software, it can be updated and improved as new knowledge and research becomes available. Ultimately it would use feedback from farmers themselves who are using the various methods, to re-evaluate or update the baseline data used (e.g. as costs change or if more limitations of a specific method is found). A feedback loop can thus be built into the DSS, allowing it to adapt to changing circumstances.

5. Conclusions

Many different approaches to human-wildlife conflict have been used in the past, with partial success. Many farmers still prefer to kill predators on their land or to engage in unsustainable farming practices, without the issue being resolved. Human-wildlife conflict still remain the major cause of death for many predators, but ultimately farmers remain the custodians of predators on their land and need to be empowered to do a better job of managing their land, including both agricultural aspects and ecological aspects of farmer-predator conflict. An online decision support system can put the relevant knowledge into the hands of farmers who are struggling with livestock depredation on their land. This is in effect using an ecologically holistic view of the farming system, looking at the whole ecosystem and not considering livestock depredation as an isolated problem (Bingham, 1997). By presenting only the top three methods with their limitations, pros and cons, the farmer will have the required information available to make informed decisions on what to do to decrease livestock losses, without being overwhelmed with irrelevant data. A DSS can also be updated periodically, making sure that it remains current. In time, the model can be expanded or adapted to include communal farming systems (Blackburn et al., 2016) and other predators.

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Babrgir, S., Farhadinia, M., Moqanaki, E., (2015). Socio-economic consequences of cattle predation by the Endangered Persian leopard Panthera pardus saxicolor in a Caucasian conflict hotspot, northern Iran. *Oryx*, 7 pp.
URL: `http://dx.doi.org/10.1017/S0030605315000903`

Bailey, A., Conradie, B., (2013). *The effect of predator culling on livestock losses: Caracal control in Cooper hunting club, 1976 – 1981.* Tech. rep., Centre for Social Science Research, Cape Town.

Balme, G., Lindsey, P., Swanepoel, L., Hunter, L., (2014). Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study. *Conservation Letters* 7 (1), 3–11.

Balme, G., Slotow, R., Hunter, L., (2009). Impact of conservation interventions on the dynamics and persistence of a persecuted leopard (Panthera pardus) population. *Biological Conservation* 142, 2681–2690.

Begg, C., Kushnir, H., (2013). *Human-Lion Conflict Toolkit.* Wildlife Conservation Network, www.appleseedesign.com.

Beinart, W., (1998). The Night of the Jackal: Sheep, Pastures and Predators in the Cape. *Past & Present* 158, 172–206.

Bergman, D., De Waal, H., Avenant, N., Bodenchuk, M., Marlow, M., Nolte, D., (2013). The Need to Address Black-backed Jackal and Caracal Predation in South Africa. *In: J.B., A., Gallagher, G. (Eds.), Proceedings of the 15th Wildlife Damage Management Conference.* Wildlife Damage Management Conference., pp. 86–94.

Bingham, S., (1997). *Grassroots Restoration: Holistic Management for Villages.* Savory Center.

Blackburn, S., Hopcraft, J., Ogutu, J., Matthiopoulos, J., Frank, L., (2016). Human–wildlife conflict, benefit sharing and the survival of lions in pastoralist community-based conservancies. *Journal of Applied Ecology* 53, 1195–1205.

Bothma, J. P., (2012). *Literature review of the ecology and control of the black-backed jackal and caracal in South Africa.* Tech. rep., CapeNature.

Bowe, R., (2000). Economy vs. Ecology. *Quivira Coalition Newsletter* 3 (2), 8–9,17.

Cadotte, M., Dinnage, R., Tilman, D., (2012). Phylogenetic diversity promotes ecosystem stability. *Ecology* 93 (8), S223–S233.

CapeNature, (Downloaded: 2016/09/15). *Landowner's Guide: Human-Wildlife Conflict Sensible solutions to living with wildlife.* http://www.capenature.co.za/wp-content/uploads/2015/05/Landowners-Guide_Human-Wildlife-Conflict.pdf.

Cardillo, M., Purvis, A., Sechrest, W., Gittleman, J., Bielby, J., Mace, G., (2004). Human Population Density and Extinction Risk in the World's Carnivores. *PLoS Biology* 2 (7), 909–914.

Caughley, G., (1976). Wildlife Management and the Dynamics of Ungulate Populations. *In: Coaker, T. (Ed.), Applied Biology Vol.1.* Academic Press, New York, NY, pp. 183–246.

Chardonnet, P., Soto, B., Fritz, H., Crosmary, W., Drouet-Hoguet, N., Mesochina, P., Pellerin, M., Mallon, D., Bakker, L., Boulet, H., Lamarque, F., (2010). *Wildlife Management Working Paper 13 - MANAGING THE CONFLICTS BETWEEN PEOPLE AND LION - Review and insights from the literature and field experience.* Tech. rep., Food and Agriculture Organization of the United Nations.

Conradie, B., Piesse, J., (2013). *The Effect of Predator Culling on Livestock Losses: Ceres, South Africa, 1979 – 1987.* Tech. Rep. 319, Centre for Social Science Research, Cape Town.

CPW, (2014). *Sustainable Wildlife Management And Biodiversity.* www.fao.org/forestry/wildlife-partnership.

Daly, B., Davies-Mostert, H., Davies-Mostert, W., Evans, S., Friedmann, Y., King, N., Snow, T., Stadler, H. (Eds.), (2006). *Prevention is the Cure. Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa.* Endangered Wildlife Trust.

De Wet, T., (2002). Doodmaak slaag nie teen probleemdiere nie. (Killing does not succeed against problem animals.). *Landbouweekblad* 4 Januarie 2002, 32–35.

DeCesare, N., Hebblewhite, M., Robinson, H., Musiani, M., (2010). Endangered, apparently: the role of apparent competition in endangered species conservation. *Animal Conservation* 13, 352–362.

Dickman, A., Hazzah, L., Carbone, C., Durant, S., (2014). Carnivores, culture and 'contagious conflict': Multiple factors influence perceived problems with carnivores in Tanzania's Ruaha landscape. *Biological Conservation* 178, 19–27.

Dickman, A., Macdonald, E., Macdonald, D., (2011). A review of financial instruments to pay for predator conservation and encourage human–carnivore coexistence. *Proceedings of the National Academy of Sciences of the USA* 108 (34), 13937–13944.

Durant, S., Mitchell, N., Ipavec, A., Groom, R., (2015). Acinonyx jubatus. *In: The IUCN Red List of Threatened Species, Downloaded on 16 February 2017*. IUCN, http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T219A50649567.en, p. e.T219A50649567.

Estes, J., Terborgh, J., Brashares, J., Power, M., Berger, J., Bond, W., Carpenter, S., T.E., E., Holt, R., Jackson, J., Marquis, R., Oksanen, L., Oksanen, T., Paine, R., Pikitch, E., Ripple, W., Sandin, S., Scheffer, M., Schoener, T., Shurin, J., Sinclair, A., Soulé, M., Virtanen, R., Wardle, D., (2011). Trophic Downgrading of Planet Earth. *Science* 333 (6040), 301–306.

Fischer, J., Lindenmayer, D., (2000). An assessment of the published results of animal relocations. *Biological Conservation* 96, 1–11.

Ford, A., Goheen, J., Otieno, T., Bidner, L., Isbell, L., Palmer, T., Ward, D., Woodroffe, R., Pringle, R., (2014). Large carnivores make savanna tree communities less thorny. *Science* 346 (6207), 346–349.

Forthman, D., (2000). Experimental Application of Conditioned Taste Aversion (CTA) to Large Carnivores. *Carnivore Damage Prevention News* 2, 2–4.

Grace, J., Anderson, T., Seabloom, E., Borer, E., Adler, P., Harpole, W., Hautier, Y., Hillebrand, H., Lind, E., Pärtel, M., Bakker, J., Buckley, Y., Crawley, M., Damschen, E., Davies, K., Fay, P., Firn, J., Gruner, D., Hector, A., Knops, J., MacDougall, A., Melbourne, B., Morgan, J., Orrock, J., Prober, S., Smith, M., (2016). Integrative modelling reveals mechanisms linking productivity and plant species richness. *Nature*, 9 pp.
DOI: `10.1038/nature16524`

Hansen, I., (2005). Use of Livestock Guarding Dogs in Norway – a Review of the Effectiveness of Different Methods. *Carnivore Damage Prevention News* 8, 2–8.

Hautier, Y., Tilman, D., Isbell, F., Seabloom, E., Borer, E., Reich, P., (2015). Anthropogenic environmental changes affect ecosystem stability via biodiversity. *Science* 348 (6232), 336–340.

Holmes, M., Holmes, R., (2006). Can caracals save sheep? Personal communication.
URL: `http://www.farmersweekly.co.za/article.aspx?id=286`

Hoogesteijn, R., Hoogesteijn, A., (2010). Conserving wild felids in humanized landscapes - Strategies for reducing conflicts between jaguars and cattle. *Wild Felid Monitor* 3 (2), 1, 10–13.

Howery, L., DeLiberto, T., (2004). Indirect Effects of Carnivores on Livestock Foraging Behavior and Production. *Sheep & Goat Research Journal* 19, 53–57.

Hunt, C., (1984). *Vol. 1. Behavioral responses of bears to tests of repellents deterrents and aversive conditioning Vol. 2. Deterrents aversive conditioning and other practices: An annotated bibliography to aid in bear management.* Ph.D. thesis, University of Montana.

Jaeger, M., (2004). Selective Targeting of Alpha Coyotes to Stop Sheep Depredation. *Sheep & Goat Research Journal* 19, 80–84.

Keehner, J., Wielgus, R., Maletzke, B., Swanson, M., (2015). Effects of male targeted harvest regime on sexual segregation in mountain lion. *Biological Conservation* 192, 42–47.

Keen, P., (1980). *Decision support systems : a research perspective.* Tech. rep., Alfred P. Sloan School of Management. Center for Information Systems Research.

Khorozyan, I., Ghoddousi, A., Soofi, M., Waltert, M., (2015). Big cats kill more livestock when wild prey reaches a minimum threshold. *Biological Conservation* 192, 268–275.

Kinnaird, M., O'Brien, T., (2012). Effects of Private-Land Use, Livestock Management, and Human Tolerance on Diversity, Distribution, and Abundance of Large African Mammals. *Conservation Biology* 26 (6), 1026–1039.

Koller, D., Friedman, N., (2005). *Probabilistic Graphical Models: Principles and Techniques.* Massachusetts Institute of Technology.

Lindsey, P., Havemann, C., Lines, R., Palazy, L., Price, A., Retief, T., Rhebergen, T., Van der Waal, C., (2013). Determinants of Persistence and Tolerance of Carnivores on Namibian Ranches: Implications for Conservation on Southern African Private Lands. *PLoS ONE* 8 (1), e52458.

Linnell, J., Aanes, R., Swenson, J., (1997). Translocation of carnivores as a method for managing problem animals: a review. *Biodiversity and Conservation* 6 (9), 1245–1257.

Linnell, J., Odden, J., Smith, M., Aanes, R., Swenson, J., (1999). Large Carnivores That Kill Livestock: Do "Problem Individuals" Really Exist? *Wildlife Society Bulletin* 27 (3), 698–705.

Linnell, J., Smith, M., Odden, J., Swenson, J., Kaczensky, P., (1996). *Carnivores and sheep farming in Norway. 4. Strategies for the reduction of carnivore - livestock - conflicts: a review.* Tech. rep., Norsk Institutt for Naturforskning.

Lukarevsky, V., (2003). Saving the Central Asian Leopard in Turkmenistan. *Carnivore Damage Prevention News* 6, 13–15.

Madden, F., McQuinn, B., (2014). Conservation's blind spot: The case for conflict transformation in wildlife conservation. *Biological Conservation* 178, 97–106.

Marker, L., (2000). Aspects of the ecology of the cheetah (Acinonyx jubatus) on North Central Namibian farmlands. *Journal of Namibia Scientific society* 48, 40–48.

Marker, L., Dickman, A., Jeo, R., Mills, M., Macdonald, D., (2003). Demography of the Namibian cheetah, Acinonyx jubatus jubatus. *Biological Conservation* 114, 413–425.

Marker, L., Dickman, A., Mills, M., Macdonald, D., (2010). Cheetahs and ranchers in Namibia: a case study. *In: Macdonald, D., Loveridge, A. (Eds.), Biology and Conservation of Wild Felids*. Oxford University Press, Ch. 15, pp. 353–372.

Marker, L., Dickman, A., Wilkinson, C., Schumann, B., Fabiano, E., (2007). The Namibian Cheetah: Status Report. *Cat News* 3, 4–13.

Marker, L., Kraus, D., Barnett, D., Hurlbut, S., (1996). *Cheetah survival on Namibian farmlands*. Cheetah Conservation Fund.

Marker, L., Mills, M., Macdonald, D., (2003). Factors Influencing Perceptions of Conflict and Tolerance toward Cheetahs on Namibian Farmlands. *Conservation Biology* 17 (5), 1290–1298.

McGranahan, D., (2011). Identifying ecological sustainability assessment factors for ecotourism and trophy hunting operations on private rangeland in Namibia. *Journal of Sustainable Tourism* 19 (1), 115–131.

McManus, J., Dickman, A., Gaynor, D., Smuts, B., Macdonald, D., (2014). Dead or alive? Comparing costs and benefits of lethal and non-lethal human–wildlife conflict mitigation on livestock farms. *Oryx* 49 (4), 687–695.

Messmer, T., (2000). The emergence of human-wildlife conflict management: turning challenges into opportunities. *International Biodeterioration & Biodegradation* 45, 97–102.

Miller, J., Jhala, Y., Jena, J., Schmitz, O., (2015). Landscape-scale accessibility of livestock to tigers: implications of spatial grain for modeling predation risk to mitigate human–carnivore conflict. *Ecology and Evolution* 5 (6), 1354–1367.

Mishra, C., Allen, P., McCarthy, T., Madhusudan, M., Bayarjargal, A., Prins, H., (2003). The Role of Incentive Programs in Conserving the Snow Leopard. *Conservation Biology* 17 (6), 1512–1520.

Montag, J., (2003). Compensation and Predator Conservation: Limitations of Compensation. *Carnivore Damage Prevention News* 6, 2–6.

Nattrass, N., Conradie, B., (2013). *Jackal Narratives and Predator Control in the Karoo, South Africa.* Tech. rep., Centre for Social Science Research, Cape Town.

Naughton-Treves, L., Grossberg, R., Treves, A., (2003). Paying for Tolerance: Rural Citizens' Attitudes toward Wolf Depredation and Compensation. *Conservation Biology* 17 (6), 1500–1511.

Nyhus, P., Osofsky, S., Ferraro, P., Madden, F., Fischer, H., (2005). Bearing the costs of human-wildlife conflict: The challenges of compensation schemes. *In: Woodroffe, R., Thirgood, S., Rabinowitz, A. (Eds.), People and Wildlife: Conflict or Coexistence?* Vol. 9. Cambridge University Press, Ch. 7, pp. 107–121.

Ogada, M., Woodroffe, R., Oguge, N., Frank, L., (2003). Limiting Depredation by African Carnivores: the Role of Livestock Husbandry. *Conservation Biology* 17 (6), 1521–1530.

Paige, C., (2015). *A Wyoming Landowner's Handbook to Fences and Wildlife: Practical Tips for Fencing with Wildlife in Mind.* Wyoming Community Foundation, 2nd Edition.

Pitman, R., (2012). The conservation biology and ecology of the African leopard Panthera pardus pardus. *The Plymouth Student Scientist* 5 (2), 281–600.

Potgieter, G., Kerley, G., Marker, L., (2016). More bark than bite? The role of livestock guarding dogs in predator control on Namibian farmlands. *Oryx* 50 (6), 514–522.

Potgieter, G., Marker, L., Avenant, N., Kerley, G., (2013). Why Namibian Farmers Are Satisfied With the Performance of Their Livestock Guarding Dogs. *Human Dimensions of Wildlife: An International Journal* 18 (6), 403–415.

Purchase, G., Marker, L., Marnewick, K., Klein, R., Williams, S., (2007). Regional Assessment of the Status, Distribution and Conservation Needs of Cheetahs in Southern Africa. *Cat News* 3, 44–46.

Ray, J., Hunter, L., Zigouris, J., (2005). *Setting conservation and research priorities for larger African carnivores.* Tech. rep., Wildlife Conservation Society.

Reiss, J., Bridle, J., Montoya, J., Woodward, G., (2009). Emerging horizons in biodiversity and ecosystem functioning research. *Trends in Ecology and Evolution* 24 (9), 505–514.

Rigg, R., Findo, S., Wechselberger, M., Gorman, M., Sillero-Zubiri, C., Macdonald, D., (2011). Mitigating carnivore–livestock conflict in Europe: lessons from Slovakia. *Oryx* 45 (2), 272–280.

Ripple, W., Estes, J., Beschta, R., Wilmers, C., Ritchie, E., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M., Schmitz, O., Smith, D., Wallach, A., Wirsing, A., (2014). Status and Ecological Effects of the World's Largest Carnivores. *Science* 343 (6167), 1241484.

Ritchie, E. G., Johnson, C. N., (2009). Predator interactions, mesopredator release and biodiversity conservation. *Ecology Letters* 12, 982–998.

Ropiquet, A., Knight, A., Born, C., Martins, Q., Balme, G., Kirkendall, L., Hunter, L., Senekal, C., Matthee, C., (2015). Implications of spatial genetic patterns for conserving African leopards. *Comptes Rendus Biologies* 338, 728–737.

Rust, N., (2016). Can stakeholders agree on how to reduce human-carnivore conflict on Namibian livestock farms? A novel Q-methodology and Delphi exercise. *Oryx* 51 (2), 1–8.
URL: `http://doi:10.1017/S0030605315001179`

Rust, N., Marker, L., (2013). Attitudes Toward Predators and Conservancies Among Namibian Farmers. *Human Dimensions of Wildlife: An International Journal* 18 (6), 463–468.

Rust, N., Tzanopoulos, J., T., H., MacMillan, D., (2016). Why Has Human-Carnivore Conflict Not Been Resolved in Namibia? *Society & Natural Resources* 29 (9), 1079–1094.

Schipper, J., Chanson, J., Chiozza, F., Cox, N., Hoffmann, M., Katariya, V., Lamoreux, J., Rodrigues, A., Stuart, S., Temple, H., Baillie, J., Boitani, L., Lacher, T. J., Mittermeier, R., Smith, A., Absolon, D., Aguiar, J., Amori, G., Bakkour, N., Baldi, R., Berridge, R., Bielby, J., Black, P., Blanc, J., Brooks, T., Burton, J., Butynski, T., Catullo, G., Chapman, R., Cokeliss, Z., Collen, B., Conroy, J., Cooke, J., Da Fonseca, G., Derocher, A., Dublin, H., Duckworth, J., Emmons, L., Emslie, R., Festa-Bianchet, M., Foster, M., Foster, S., Garshelis, D., Gates, C., Gimenez-Dixon, M., Gonzalez, S., Gonzalez-Maya, J., Good, T., Hammerson, G., Hammond, P., Happold, D., Happold, M., Hare, J., Harris, R., Hawkins, C., Haywood, M., Heaney, L., Hedges, S., Helgen, K., Hilton-Taylor, C., Hussain, S., Ishii, N., Jefferson, T., Jenkins, R., Johnston, C., Keith, M., J., K., Knox, D., Kovacs, K., Langhammer, P., Leus, K., Lewison, R., Lichtenstein, G., Lowry, L., Macavoy, Z., Mace, G., Mallon, D., Masi, M., McKnight, M., Medellin, R., Medici, P., Mills, G., Moehlman, P., Molur, S., Mora, A., Nowell, K., Oates, J., Olech, W., Oliver, W., Oprea, M., Patterson, B., Perrin, W., Polidoro, B., Pollock, C., Powel, A., Protas, Y., Racey, P., Ragle, J., P., R., Rathbun, G., Reeves, R., Reilly, S., Reynolds, J. I., Rondinini, C., Rosell-Ambal, R., Rulli, M., Rylands, A., Savini, S., Schank, S., Sechrest, W., Self-Sullivan, C., Shoemaker, A., Sillero-Zubiri, C., De Silva, N., Smith, D., Srinivasulu, C., Stephenson, P., Van Strien, N., Talukdar, B., Taylor, B., Timmins, R., Tirira, D., Tognelli, M., Tsytsulina, K., Veiga, L., Vié, J., Williamson, E., Wyatt, S., Xie, Y., Young, B., (2008).

The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge. *Ecology* 322 (5899), 225–230.

Schumann, M., (2004). *Guide to integrated livestock and predator management.* Cheetah Conservation Fund, P.O. Box 1755, Otjiwarongo, Namibia.

Shelton, M., (2004). Predation and Livestock Production: Perspective and Overview. *Sheep & Goat Research Journal* 19, 2–5.

Shivik, J., (2004). Non-lethal Alternatives for Predation Management. *Sheep & Goat Research Journal* 19, 64–71.

Shivik, J., (2006). Tools for the Edge: What's New for Conserving Carnivores. *BioScience* 56 (3), 253–259.

Shivik, J., Tregenza, T., Callahan, P., (2003). Nonlethal Techniques for Managing Predation: Primary and Secondary Repellents. *Conservation Biology* 17 (6), 1531–1537.

Smuts, B., (2008). *Predators on Livestock Farms - A Practical Farmers' Manual for Non-lethal, Holistic, Ecologically Acceptable and Ethical Management.* Landmark Foundation, www.landmarkfoundation.org.za.

Snow, T., (2009). *A Systems-Thinking Based Evaluation of Predator Conflict Management on Selected South African Farms.* Master's thesis, University of KwaZulu-Natal.

Sprague, R. J., (1980). A Framework for the Development of Decision Support Systems. *MIS Quarterly* 4 (4), 1–26.

Stander, P., (1990). A suggested management strategy for stock-raiding lions in Namibia. *South African Journal of Wildlife Research* 20 (2), 37–43.

Stander, P., //au, K., /ui, N., Dabe, T., Dabe, D., (1997). Non-consumptive utilisation of leopards: Community conservation and ecotourism in practice. *In: Proceedings of a Symposium on Lions and Leopards as Game Ranch Animals.* Desert Lion Conservation Project, Desert Lion Conservation Project, pp. 50–57.

Stein, A., Athreya, V., Gerngross, P., Balme, G., Henschel, P., Karanth, U., Miquelle, D., Rostro-García, S., Kamler, J., Laguardia, A., Khorozyan, I., Ghoddousi, A., (2015). Panthera pardus. *In: The IUCN Red List of Threatened Species, Downloaded on 16 February 2017.* IUCN, http://www.iucnredlist.org/details/summary/15954/0, p. e.T15954A102421779.

Stein, A., Fuller, T., Damery, D., Sievert, L., Marker, L., (2010). Farm management and economic analyses of leopard conservation in north-central Namibia. *Animal Conservation* 13, 419–427.

Stone, S., Fascione, N., Miller, C., Pissot, J., Schrader, G., Timberlake, J., (2008). *Livestock and Wolves - A Guide to Nonlethal Tools and Methods to Reduce Conflicts.* Defenders of Wildlife.

Swanepoel, L., Somers, M., Van Hoven, W., Schiess-Meier, M., Owen, C., Snyman, A., Martins, Q., Senekal, C., Camacho, G., Boshoff, W., Dalerum, F., (2015). Survival rates and causes of mortality of leopards Panthera pardus in southern Africa. *Oryx* 49 (4), 595–603.

Terborgh, J., (2015). Toward a trophic theory of species diversity. *PNAS* 112 (37), 11415–11422.

Thorn, M., Green, M., Dalerum, F., Bateman, P., Scott, D., (2012). What drives human–carnivore conflict in the North West Province of South Africa? *Biological Conservation* 150, 23–32.

Thorn, M., Green, M., Marnewick, K., Scott, D., (2015). Determinants of attitudes to carnivores: implications for mitigating human–carnivore conflict on South African farmland. *Oryx* 49 (2), 270–277.

Treves, A., (2009). Hunting for large carnivore conservation. *Journal of Applied Ecology* 46, 1350–1356.

Treves, A., Bruskotter, J., (2014). Tolerance for Predatory Wildlife. *Science* 344, 476–477.

Treves, A., Karanth, K., (2003). Human-Carnivore Conflict and Perspectives on Carnivore Management Worldwide. *Conservation Biology* 17 (6), 1491–1499.

Treves, A., Karanth, K., (2003). Special Section: Human-Carnivore Conflict: Local Solutions with Global Applications. *Conservation Biology* 17 (6), 1489–1490.

Van Bommel, L., (2010). *Guardian Dogs: Best Practice Manual for the use of Livestock Guardian Dogs.* University of Canberra, Kirinari Street, Bruce ACT 2617.

Van Niekerk, H., (2010). *The cost of predation on small livestock in South Africa by medium-sized predators.* Master's thesis, University of the Free State.

Weilenmann, M., Gusset, M., Mills, D., Gabanapelo, T., Schiess-Meier, M., (2010). Is translocation of stock-raiding leopards into a protected area with resident conspecifics an effective management tool? *Wildlife Research* 37, 702–707.

Weise, F., Lemeris, J. J., Munro, S., Bowden, A., Venter, C., Van Vuuren, M., Van Vuuren, R., (2015). Cheetahs (Acinonyx jubatus) running the gauntlet: an evaluation of translocations into free-range environments in Namibia. *PeerJ* 3, e1346.

Weise, F., Lemeris, J. J., Stratford, K., Van Vuuren, R., Munro, S., Crawford, S., Marker, L., Stein, A., (2015). A home away from home: insights from successful leopard (Panthera pardus) translocations. *Biodiversity and Conservation* 24, 1755–1774.

Woodroffe, R., Frank, L., Lindsey, P., ole Ranah, S., Romañach, S., (2007). Livestock husbandry as a tool for carnivore conservation in Africa's community rangelands: a case–control study. *Biodiversity and Conservation* 16, 1245–1260.

Yoder, J., (2000). Damage abatement and compensation programs as incentives for wildlife management on private land. *In: Human Conflicts with Wildlife: Economic Considerations.* USDA National Wildlife Research Center Symposia. USDA National Wildlife Research Center, USDA National Wildlife Research Center, pp. 17–28.