Human-Predator Conflict: A new approach needed

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Abstract

Although many methods has 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 has 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 livestock farmers in North Central Namibia. We propose a more useful classification of methods than the usual lethal non-lethal dichotomy, and compare the various methods in terms of their success and cost-effectiveness. We also 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
PACS: mitigating methods, Namibia, sustainability

1. Introduction

Human-wildlife conflict is a growing global problem [111, 167, 122]. This has implications both for agriculture and for conservation. Indeed, some authors have considered the conflict to be human-human conflict between agriculturalists and conservation ecologists, rather than between farmers and wildlife [166, 32, 119]. This imply that any solution to the conflict should address both

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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" [79], "farmer-predator conflict" [130] will be used interchangeably, with the understanding that "human-wildlife conflict" as used here refers not only to carnivores in general (which includes scavengers), but specifically to conflict arising from depredation of livestock. We will be focussing on commercial livestock farming in Namibia, while keeping in mind that the same methods could work in other areas with similar circumstances and predators. The issue of game farming and conflict caused by depredation of valuable game animals, is really a separate question and will not be considered here.

From an ecological perspective it is known that the greatest threat to large mammalian carnivores and sharks is direct killing by humans [165], an even greater immediate threat than habitat destruction, especially in Africa [133]. This includes killing of carnivores in retaliation for livestock depredation [123]. Large carnivores, often apex predators, need large home ranges or territories to sustain themselves, making them more vulnerable to extinction [26, 145]. This is exemplified by the cheetah (*Acinonyx jubatus*), classified as vulnerable in the IUCN Red List [44]. In Namibia, the country with the largest surviving population of cheetahs in the world [96, 106, 44], an estimated 90% of cheetahs are found on commercial livestock farms (private ranches) outside formally protective reserves [97, 99] with being shot on livestock farms the major cause of death [103]. In Southern Africa, most of the near-threatened [65] leopard (*Panthera pardus*) habitat is found outside protected areas and the major threat to leopard survival is direct killing by people[160]. 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 40). With farmers as the custodians of the majority of land in most countries of the world, the ultimate survival of many species are squarely in the hands of farmers.

A telephone survey by Van Niekerk [171] showed that livestock farmers in South Africa claimed a total annual loss of R 1 390 453 062 worth of livestock directly to predators [17]. These losses were unequally distributed with some districts and some farmers having much higher losses than the average (see also 32). Similarly, data from the official government-sponsored hunting clubs for the period 1979-1987 in the Ceres South district [32]and Cooper hunting club 1976-1981 outside Mossel Bay [7] showed average losses of 1.48 livestock units per farm and 0.94 sheep per farm per year, but with highs of up to 114 sheep lost in a single year to predators on a single farm. In the area around the Waterberg in North-Central Namibia, farmers lost on average 3.8% of their calves to depredation annually (US$1370 per farm per year according to 158). In a slightly wider area of North-Central Namibia, Marker et al. [106] found that farmers who claimed cheetah problems on average lost 16.7 (2%) of their cattle and 18.0 (5.3%) of their small livestock per year for the period 1991-1993 and those who claimed cheetahs as not problematic lost on average 6.8 (1.3%) of their cattle and 11.5 (4.3%) of their small livestock to predators. In 1993-1999 the numbers changed to an average of 5.8 cattle lost per year by

farmers who claimed cheetahs as problematic and 1.2 by those who did not consider cheetahs problematic, while they lost on average 8.5 and 12.1 small livestock respectively. Lindsey et al. [86]found the average annual livestock losses reported due to leopards over most of Namibia's commercial farm areas to be US$2,644/farm to leopards, almost double that reported by Stein et al. [158] earlier. If we keep in mind that we might have a similar uneven distribution of livestock depredation between farms as shown by Conradie and Piesse [32] in the Ceres Karoo, the losses of some individual farmers could be very high. These kinds of losses are not economically insignificant, and a study at the Glen Agricultural Institute near Bloemfontein in the Free State, found that black-backed jackal (*Canis mesomelas*) and caracal (*Caracal caracal*) depredation of the Merino and Dorper sheep made it ultimately unsustainable [17]. In addition to direct losses, Howery and DeLiberto [68] make the point that behavioural changes in livestock because of predation risk, can cause significant decreases 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 [122].

Predators fulfil an important role in functioning ecosystems, and their extermination has many unintended consequences, including trophic cascades [136] and extinctions [47, 38], meso-predator release [137], and savannah ecosystems becoming dominated by more thorny trees and shrubs [51]. Ultimately, the persistence of ecosystem services [134, 34, 56] and the stability of ecosystems as such, are dependent on its biodiversity [25, 63], and there is good reason to believe that predators are a major driver of high biodiversity [161]. E.g. the leopard, an apex predator, has been considered as a reliable indicator of a healthy ecosystem [128]. Extensive livestock farming is ultimately dependent on sustainable ecosystem services for its own survival as a viable economic activity [22]. For both the economic survival of livestock farmers and the persistence of relatively species-rich ecosystems on livestock farms [81], it is important that solutions to farmer-predator conflict be found.

2. Past approaches

Many different methods have been proposed and implemented in the past to mitigate human-wildlife conflict (HWC). In general these methods varied 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). Methods for mitigating HWC have generally been classified as "lethal" or "non-lethal" (e.g. 35, 148), the general implication being that "lethal" methods are not environmentally friendly or ecologically sustainable and that "non-lethal" methods are to be preferred. However, this classification runs into problems when it is realized that a generally accepted "non-lethal" method, like using livestock guarding dogs, can be very lethal indeed, and might even be approved by farmers because it is lethal to some predators (e.g. 130, 131)! Additionally, a "non-lethal"

method like relocation of problem predators, sometimes not only fail to stop livestock depredation on the farm from which the predator has been removed [88], but in the case of territorial animals like leopards, 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 [77, 12], 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 [50, 174, 175, 176]. In effect, a so-called "non-lethal" method still result in the death of one one or more predators [166] and some conservationists conclude that it is sometimes better to simply kill problem individuals, rather than trying to relocate them [155, 138]. Some researchers have questioned the very existence of such "problem animals" [89].

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 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 [166] 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 17, 139). 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 without the aim to eradicate them from farmlands. This is seldom effective [166] and can even worsen the situation for both farmers and the ecosystem [32, 7, 20, 36]. 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 [166]. This would result in either the second endpoint (farming unsustainable) if unsuccessful or the last endpoint (peaceful coexistence) if successful. Treves and Karanth [166] split these non-lethal

methods into either methods that change predator behaviour or methods that physically keep predators separate from livestock. Shivik [148] subdivided non-lethal methods into three, 1) altering human behaviour, 2) altering husbandry or 3) altering predator behaviour. In truth, since all of these methods will 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 [95] 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. [90] 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, whether a "carnivore species / population is abundant, with no danger of global or regional extermination"; or a "carnivore species / population is rare with a risk of regional and / or global extermination." They still use the familiar division of methods into lethal and non-lethal, with lethal methods exclusively used in the "outside area" zone and only non-lethal methods used in the "conservation zone". However, they were looking at HWC in a Norwegian or European context, which differs substantially from the Southern African situation.

Given that non-lethal methods are not always "non-lethal" and that "lethal" methods can occasionally be better from both an ecological and an agricultural point of view, it is proposed that a more useful view of methods when evaluating them for management decision-making might be a threefold classification:

1. Preventative (pre-emptive) methods that attempt to prevent livestock depredation by carnivores. Both lethal (e.g. eradication of predators) and non-lethal methods [148, 35, 149] could be used.
2. Incentive (compensation/offset) methods (e.g.157, 114). Generally these methods 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. Once again, both non-lethal methods (non-consumptive use) and lethal methods (e.g. trophy hunting of predators) could be used.
3. Reactive methods that only react to livestock depredation, rather than trying to prevent it. Although many of these methods seem essentially the same as methods used in the previous two groups (e.g. hunting of predators), the fact that they are only used in reaction to actual livestock losses, means that they differ both in costs and effectiveness. They can be cheaper to implement (less often used) and have a smaller negative

effect on the range-land ecosystem on farms, while having a higher risk of livestock losses.

Using this classification, we can now examine the different methods used in the past. Frequently the "same method" can be used in more than one of these three ways with different costs and effectiveness and should thus be considered as different methods. For evaluation purposes, the pros and cons as well as limitations of each method are mentioned. Pros (advantages) as used here, are positive aspects of the specific method that can be put on a scale of 1 to 10 while cons (disadvantages) are negative aspects of the method that can also be plotted on a scale of -1 to -10. Limitations measures the practicality of a method with a binary value of either true (practical in these circumstances) or false (impractical in other circumstances).

In parts of Namibia, because of grazing and drinking water limitations, farms larger than 20 000 ha and with single camps of 5000 ha are not uncommon, making some otherwise good methods simply impractical. Farming enterprises are generally considered as 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. These are not clear-cut categories and most farms fall somewhere on a scale between very intensive (e.g. typical of a dairy farm with small pastures of cultivated grazing crops, cows walking only very short distances per day, each cow handled twice per day and receiving individualized feeding based on milk production, expensive infrastructure and fairly labour-intensive or mechanized) to very extensive (large herds of livestock basically free-ranging with few water points available, having to walk long distances to get to grazing and drinking water, gathered and handled only once every six months and then moved to whatever part of the farm has received rain within the previous year). Even on the same farm, different livestock species or breeds can be managed at different levels between intensive and extensive, with small livestock for example, sleeping in a kraal every night and being counted daily, while cattle are free-ranging in camps further away from the farm homestead and only gathered once or twice a year. Different limitations will determine how intensive the farming system can be, including availability of drinking water points, rainfall and stocking rates that can be sustained on the land, terrain and impassibility of roads, current infrastructure on the farm, capital available to the farmer for improvements, if the farmer is doing other work for an additional income (so-called "weekend farmers"), etc. After considering various measures of intensive *versus* extensive farming, including stocking rates (livestock units per hectare per year), economic carrying capacity, size of the farm, number of labourers, infrastructure and mechanization, etc. all of which can be relevant, it was decided to use a simplified classification of farming systems by how often the farmer sees or handles all the livestock on his farm. For the sake of considering its importance as a limiting factor for methods to decrease livestock depredation, 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.

2.1. Preventative methods

2.2. Compensatory methods

2.3. Reactive methods

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. 90, 150, 146, 148, 35, 149, 152, 159, 31, 169, 14, 127), it is still a growing problem [111, 67]. Snow [153] 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. One very important insight, is the realization that the final managers and implementers of any method used to reduce HWC are the farmers themselves [178]. Hoogesteijn and Hoogesteijn [67] makes the important point that ranchers (livestock farmers) should be considered as partners in conservation rather than opponents. The current increase in cheetah numbers in Namibia [104, 132] can be directly ascribed to an increase in tolerance of cheetahs by farmers [106]. And yet, conflict with farmers remain the main threat to the long-term survival of Namibian cheetahs [44]. Farmers are either not using the available methods, or the methods they do use, are not working. This can partly be explained by the fact that farmers experience intra-group conflict [95] and are not a homogeneous group, with a significant minority of Namibian farmers still preferring lethal methods to non-lethal alternatives [139]. McManus et al. [110] demonstrated that at least some non-lethal methods are more cost-effective than the lethal methods on Eastern Cape farms, and yet, 64% of the participating farmers resumed using lethal methods after the research period (although most combined it with the non-lethal methods).

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 [123, 106, 150, 86, 140, 39]. However, this was not the only or even the most important predictor of farmer tolerance of predators. What is often not kept in mind, is that the risk of depredation losses can influence the attitude of a livestock owner just as much or even more than actual losses. Paradoxically, other studies have shown that in some cases the actual number of livestock losses to predators have little influence on farmer attitudes [6, 162, 163] and compensation for losses do little to change livestock owners' attitudes [116, 120, 95]. But why?

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 [116, 166, 32, 95]. Nattrass and Conradie [119] 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 [25] this means that farmers and conservationists share all their aims, except for the two agricultural aims (maximizing production and minimizing livelihood risk). One would therefore expect the two groups to be natural allies, but that does not always happen. One reason for the lack of cooperation might be because farmers do not often have an ecosystem-wide view of their farms and thus do not realize the importance of biodiversity for the sustainability of their farming enterprises. On the other hand, conservationists also often focus on one or a few carnivore species when communicating with farmers, and therefore share part of the blame for this blinkered view of the issues. Bowen [23] makes the important point that our aim should be to conserve *functioning* ecosystems (the processes of life), rather than simply genes, species or even ecosystems.

Madden and McQuinn [95] 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 [162, 163]. They describe the use of conflict transformation tools to help solve these underlying, complex social conflicts[95]. In this model, conflict can be seen as being at three levels of depth with three different approaches needed to transform the situation from an "us *versus* them" situation to one of a genuine "we", working together in order to reach our aims of biodiversity, sustainability and livelihood production with minimum conflict, risks or costs (Figure 1 on page 10).

- The most superficial level of conflict and the one addressed by all these methods discussed in the previous section on page 3 to prevent, compensate or react to human-wildlife conflict, is known as a dispute. It is typified by the interaction between two strangers with no previous history, becoming involved in conflict that is fairly easily resolved by an agreed settlement on how the dispute should be resolved (i.e. an implementation of one or more of the HWC mitigation methods discussed in our context acceptable to both sides).

- When the two parties have a history of past unresolved disputes, this is typical of some underlying conflict. Because farmers often do not distinguish between different conservation NGO's and the government's Ministry of Environment and Tourism, simply grouping them all together as conservationists, negative previous experiences with any of these groups can cause underlying conflict that will not be solved by "quick answer" methods for resolving human-wildlife conflict. E.g. a promise by nature conservation personnel that they will translocate any captured leopards from farmlands to a national park, followed by promises, but no actions after repeated telephone calls from a farmer who had to feed the captured

leopard for more than a week, led not only to the leopard being shot, but to farmers in the whole district distrusting any promises or information from anybody involved with nature conservation about predators (personal observation). Trust has been broken, and any conflict resolution approach that do not first rebuild the trust, will never work. Similarly, all farmers are not the same, nor share the same basic views on predators and the desirability of coexistence on farmlands [139], but past experiences with some farmers is one reason why many conservationists do not consider livestock farmers as their natural allies in conserving biodiversity. At this level of conflict, not only the specific instance of farmer-predator conflict (the current dispute) needs to be resolved, but all those past unresolved disputes also need to be addressed before a true resolution of the underlying conflict can result. If conservationists (and farmers associations) are not aware of these kind of past histories, it can cause lots of frustrations when superficial settlements do not result in the expected cooperation.

- Identity conflict is the third and deepest level of conflict and involves values, beliefs, or social-psychological needs that are central to the identity of at least one of the parties involved in the conflict. One very important motivating reason for any young man to choose farming as career, is that you work for yourself. Few (if any) farmers choose it as a career primarily for economic reasons. Thus independence from undue outside influence is an important motivating factor for farmers, and they can experience any efforts by conservationists to protect predators on farmlands as an attack not only on their livelihoods, but also on their identity as independent farmers. On the other hand, for conservationists whose identity focus on the conservation of wildlife, any action that threaten to extirpate a species may be considered as a profound moral violation. Typical of this level is a strong "us *versus* them" view of human-carnivore conflict. Communication between the groups become minimal and the little communication there is, is often misunderstood or interpreted in a prejudicial way. Reconciliation only becomes possible once both sides make a definite decision that they need each other as partners to find practical solutions to a common problem. Building trust in small steps through being transparent and honest about your own viewpoint as well as fair and truly sympathetic to the other viewpoint, is important for reconciliation. Madden and McQuinn [95] mentions that 1) process, 2) relationships and 3) substance are the three aspects that needs to be addressed in order to make peace.

Process factors relate to decision-making design, equity and authority, and how (and by whom) these are exercised (see also 159). For example, just the size of Namibian farms makes any method that depends on legal threat or compliance checking impractical, if it is not supported by the farmer who owns and manages the land. 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" (67; various Namibian farmers, personal communication). Montag [116] mentions

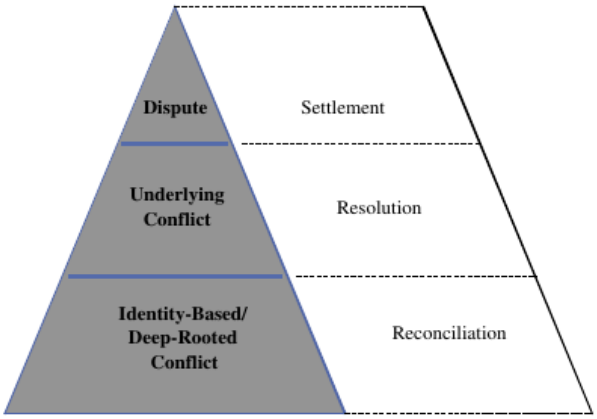

Figure 1: The conflict triangle from Madden and McQuinn [95] showing different levels of conflict and the response needed to truly "make peace".

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. [141] and Rust [139]. Madden and McQuinn [95] 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 [157, 92, 114] and thus shared ownership of the final solutions.

Rust et al. [141] make the point that farmer-predator conflict in Namibia also has politico-social and personal relationship aspects, so that something that appears to have little connection to human-wildlife conflict, namely the labour relations between farmers and their workers, can have an effect on farmer-predator conflict. Building relationships through transparency and trust, is the second aspect of reconciliation needed for conflict resolution mentioned by Madden and McQuinn. They show the importance of such relationship building by the example of conservationists finding a solution to human-elephant conflict through asking questions and consulting with a local community, resulting in a decision to use various kinds of fences. However, when they later tried to apply the same method in other communities without a similar period of consultation and trust relationship building, those same methods did not succeed, with community members failing to implement or maintain chilly peppers and breaking

down fences.

The final and perhaps most obvious part of resolving deep-rooted identity conflict, involves the actual substance of practical and cost-effective methods to mitigate farmer-predator conflict. Here the suitability of a certain method to conditions on a certain farm has often not been considered sufficiently. A number of researchers have mentioned that predation losses does not seem to be uniformly distributed, even within the same district [32], and some farmers might have extremely high depredation losses, while the majority have relatively few losses [171]. This appears to be an international feature of farmer-predator conflict, with similar reports for example, from Slovakia [135] and the USA [147]. But different levels of depredation also imply that different management decisions and different anti-predation methods are required.

To summarize some of the main reasons why past human-carnivore conflict mitigation approaches still fail to reduce the conflict:

1. They 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.
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. 141) while ignoring the deeper levels of conflict [95] between the ecological and the agricultural basic starting points [119] that 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. 17 when commenting on 35). 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, is seldom explicitly recognized. Farmers associations and agricultural unions are seldom put in the situation where they can share ownership of ecologically sound solutions to human-wildlife conflict (*cf* 92).
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".
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 152, 35). 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 [150]. Not only the ignorance of limitations, but also the incorrect implementation of methods can end in failure, with the same negative end result.

5. Rust [139] found that the single most popular method for mitigating HWC was conservation education and husbandry training to reduce livestock depredation. It is often amazing how little farmers know about the general behaviour of the predators found on their land. Not only farmers, but even behavioural ecologists, still have great gaps in our knowledge of predator behaviour outside protected areas [11]. As farms have become larger in order to remain economically viable and farming methods are often more extensive than they used to be [119], 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 dehorning 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. [105], might be confirmation of the need for knowledge, showing that how well protection measures are implemented is possibly more important than which method is used.
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 [148, 35, 149, 152, 159, 31], 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.
7. Because farming is inherently risky, farmers tend to be risk-averse and to keep to what they know. The problem with this approach is that circumstances have changed and keep on changing. Methods that were affordable and effective in the past, are so no longer because of changes in costs, legislation, ecological changes, etc.

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

Shivik [149] 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 [90]. What works well against some predators and in some circumstances, will fail in different situations. And, 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. For this reason, Shivik [148] proposed that livestock depredation control should be approached similarly to Integrated Pest Management (IPM). But it is 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 mentioned above. It is 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. The process by which any specific method is chosen and recommended should also be clear and transparent to the farmer in order to avoid any unexpected nasty surprises during implementation.

So what should we do differently from what has already been tried? It should be clear by now the the primary decision-maker and ultimate implementer of any methods to decrease conflict with predators and livestock losses, should be the livestock farmer himself, since he will ultimately have to bear the costs of any method that he decide on as well as having to deal with the consequences, whether good or bad [178]. It seems clear that conservation of larger predators is not possible without including livestock farmers in the process. But the common request for conservation education and husbandry training [139] show that farmers need the right information in their hands on both the agricultural cost-effectiveness of different methods and its ecological sustainability. One of the most important aspects of applying any predation-prevention method, is the good record keeping of the current situation on the farm [159]. 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 [67] actually consider it as a preventative method by itself. It should be pointed out that good record-keeping is not necessarily correlated to how intensive the farming system is. Even when livestock is only seen once every six months, through the use of individual ear tags, together with a weighing scale, the history of every cow can be recorded and used in breeding and other management decisions. Computer expert systems that capture expert human knowledge and use it in various applications, have existed since the 1970s and became relatively popular in the 1980s. A decision support system (DSS) is a specific type of expert systems where the aim is not so much automation or artificial intelligence, but to provide human decision makers with the relevant information needed to make an informed decision [78, 154].

Using a DSS avoids a number of the possible reasons for the past failure of mitigating methods to reduce HWC. Because it is not a person "telling the farmer what to do on his own farm", at least part of the common underlying distrust of conservation scientists [119] or past bad experiences with specific conservationists, 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, not only does it make it easier to trust it, but if 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 various methods, to re-evaluate or update the basic data used (e.g. as costs change or if more limitations of a specific method is found). A feedback loop is thus built into the DSS allowing it to adapt to changing circumstances (e.g. changes in costs of different methods). The algorithm used will include both the short-term agricultural economic cost-effectiveness of the various methods and the long-term ecological sustainability in order to choose the most appropriate method for the specific situation on a farm as entered by the farmer. 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 [18]. 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.

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. It 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 [19] and other predators.

AppendixA. Details of different HWC mitigating methods

AppendixA.1. Preventative methods

Active hunting of predators has been one of the first methods used in the Cape of Good Hope by Dutch farmers. It appears seemingly obvious that getting rid of the predators will prevent carnivores from killing livestock, which is one reason why this method is still favoured by some farmers [139]. Killing predators can be done with a number of different objectives, however [90]: .

- causing local extermination of a carnivore species (e.g. 122),
- reducing the carnivore population to a lower level,
- preventing carnivores from colonising areas with high conflict potential,
- selectively removing individual carnivores.

Of these different aims, the selective removing of individual predators is not pre-emptive, since the predator must first kill livestock (repeatedly) before it can be identified as a "problem individual". Historically a number of methods have been used to exterminate predators from farmlands [15, 17, 119]..

AppendixA.1.1. Hunting to exterminate predators

Active hunting of predators resulted in the extermination of most of the larger predators like lions from farmlands [15]. However, it was not successful against jackals and caracals on its own [36, 37], illustrating that different predators are often differently impacted by hunting [82]. Instead, the numbers of jackals and caracals actually increased as the larger predators were removed from the land because of meso-predator release [137]. From the the time of Van Riebeeck (1650's) until the 1950's when it was finally replaced by hunting clubs, a bounty system was commonly used as added incentive to kill predators. As could be expected, this system was abused in various ways [15, 119]. In recent decades, techniques have changed to include hunting by night using sound recordings (of prey or other predators) and spotlights to "call" predators, or shooting from the air using helicopters. Often semi-professional hunters are paid to "get rid" of the predators on a farm..

- Advantages: Once a predator species has been locally extirpated in a whole district or larger ecosystem, it is relatively cheap to maintain. Among other things, it means that livestock can freely range on the land without the need for kraaling or herding, leading to longer grazing times, better veld utilization and higher productivity if used together with camps and rotational grazing. It is also relatively simple to implement, with little need for specialized knowledge or equipment. In highly transformed landscapes, with little or no natural prey available to predators (and livestock being their only possible source of food), it is often the only realistic short-term option. It can also be combined with other methods to eradicate and then exclude predators from specific parts of a farm. According to Shwiff and Bodenchuk [151], in addition to the livestock saved, it can also have secondary tangible advantages (e.g. more game because of predator control) and intangible advantages (like farmers being more positive towards conservation because they are allowed to kill predators). However, they also make the very questionable statement that "it is desirable but not necessary to achieve economic efficiency in predation management programs".

- Disadvantages: Since hunting is relatively labour intensive, it is also expensive in terms of time and money initially. It can be very expensive, especially when professional hunters and helicopters are used. It is very unlikely to succeed, except for conspicuous, large predators that are easy to find and kill [15, 82]. Killing these top predators have other unwanted results, like an explosion in numbers of medium-sized predators (meso-predator release) and often do not solve the actual problem of livestock

depredation (and as shown by 32, might actually increase livestock losses). Using a 60 year data set, Berger [16] showed that although US government-subsidised predator control was very effective in killing predators, specifically coyotes, it had no effect on sheep production.

- Limitations: Unless there are official government support, with all farmers and land-owners in a district working together, it is very unlikely to succeed. It is thus not practical for a single farmer to implement without the support of all his neighbours. Moreover, it is really only suitable to transformed landscapes (e.g. cultivated pastures) where no natural habitat or prey survive for predators (e.g. parts of Europe) and not well suited for most of Africa [90]. Factors like rainfall, topography and soil fertility also limits the practicality of deliberately transforming the vegetation. Where the predator species are endangered or otherwise important for a functioning and sustainable ecosystem, this method is not an option.

AppendixA.1.2. Hunting with dogs for eradication
Dogs are often used together with hunting for exterminating predators. Therefore it shares the same advantages and disadvantages as hunting for eradication, while adding a few extras. Already in the early 1800 Lord Charles Somerset introduced the English sport of fox hunting to the Cape for hunting jackals. By this time most larger predators had already been extirpated and jackals were the major remaining cause of livestock depredation for sheep farmers. Since 1962 breeding centres for hunting hounds were established in a number of places in the old Cape Province, and even later Oranjejag, in the Free State province, used dogs for hunting [35, 17]. This method has also recently been used in Namibia with "great success", if success is measured as numbers of carnivores killed (Rothauge 2014, personal communication)..

- Advantages: Using smell, dogs can be much more effective in finding predators than human trackers alone. However, a group of well-trained dogs are probably still cheaper than using helicopters or professional hunters. This method is therefore more likely to succeed against smaller predators like jackals and caracals than hunting without dogs for the extermination of predators.

- Disadvantages: The greatest disadvantage of using dogs have been the indiscriminate nature of their hunting behaviour. Even well-trained dogs that can distinguish between prey animals (which should not be killed for various reasons) and carnivores, do not generally differentiate between damage-causing predator species and other carnivores, with the result that many non-target carnivores like bat-eared foxes, Cape foxes, aardwolves, servals, and African Wild Cats are killed as well [20]. More-over, even among the target species the individuals are killed indiscriminately. For eradication hunting with dogs has been a dismal failure, resulting in many predators killed, but with little long-term decrease in predator numbers or livestock depredation [35]. Additionally, dogs can have a devastating

effect on the natural prey of predators and on innocent carnivores and if not well-trained, can even kill livestock. If outside dog packs are rented to kill predators, some dog handlers only use male dogs in their hunting pack, knowing full well that male dogs often will not kill female jackals, thus ensuring that they will have work in the following years when the female had bred again. Needless to say, eradication will never happen.

- Limitations: Good hunting dogs require good training. This is both time-consuming and not always effective when considering the number of non-target animals typically killed. It has similar constraints than hunting to eradicate predators, with the need for at least district-wide collaboration, government support to make it affordable, and transformed landscapes with compromised ecosystems and very little natural habitat or prey to have any real chance of decreasing livestock losses.

Poison bait to exterminate predators
Poison were being used in the Cape for eradicating problem predators from the 1880's [15, 17]. Different poisons have been used, including Strychnine, Compound 1080 (Sodium monofluoroacetate), Sodium Cyanide, and Thallium Sulphate [90]. The use of poisons were largely discontinued and replaced with jackal-proof fencing and hunting clubs in the early 1900, mostly because of the ineffectiveness of poison, in addition to the negative ecological side-effects [15]. Poison can applied in different ways, including poisoning carcasses, bait, coyote getters, and poisoned collars. Because poison collars normally include the death of the livestock animal that are killed by the predator, it is considered a reactive method and not discussed here..

- Advantages: The only real advantage that poisons have, is that it is easy to use and some poisons are easy to acquire. But is this truly an advantage?

- Disadvantages: It is almost impossible to use poison to selectively kill predators. Historically it has been more successful in killing scavengers than predators [15]. Moreover, while killing many non-target carnivores, poison has not been able to exterminate jackals or decrease livestock losses.

- Limitations: Poison is an indiscriminate killer and not really effective for reducing livestock depredation. Historically it was discontinued in the early 1900's already, mostly because it was found to be ineffective [15]. It also has far-reaching negative ecological effects. Overall, it has a lot of disadvantages, targeting scavengers, rather than predators, being indiscriminate and largely ineffective, it has almost nothing in its favour except ease of use.

Some methods are used, not to exterminate all predators from farmlands, but simply to decrease their numbers. However, such attempts are unlikely to work, unless predator numbers are either close to the maximum equilibrium density (K) of the predators or close to total extermination of the predators (see Figure A.2 on the following page)..

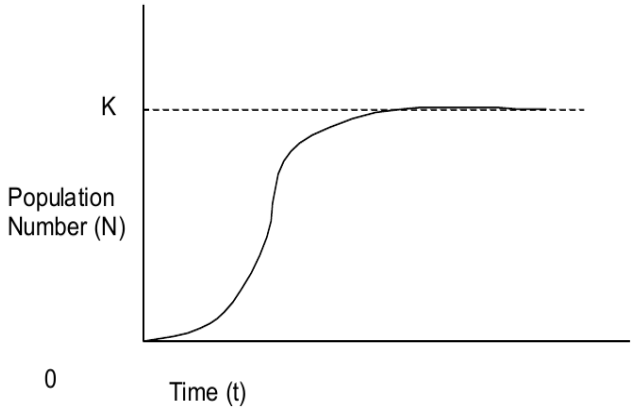

Figure A.2: The typical S-shaped logistic growth curve. By pushing predator numbers down from the equilibrium density (K), the growth rate (i.e. recruitment of new young predators) will increase. This is often not what farmers expect.

AppendixA.1.3. Hunting to reduce carnivore numbers
Many farmers realize that it is impractical to attempt eradication of all predators. And most farmers prefer not to kill predators at all, if it did not threaten their livelihood [140, 139]. Instead of trying to eradicate all predators, some farmers still shoot predators on sight, just to "keep their numbers down". In contrast to the attempts to eradicate predators, usually little extra effort or money is spend to actively hunt predators. Instead, the farmer simply keeps his rifle with him when driving through his farm and shoot any potential predators of livestock that chance to cross his path during the day (Francois Kok, 2015, personal communication). Many attempts that start off with the aim of eradication, end up as an attempt to simply keep predator number down. Other methods have also been used to try and reduce predator numbers, like denning (killing predator pups with fumigating poisons within their dens) or contraception, but these methods are impractical or ineffective for most farmers. .

- Advantages: This is one of the cheapest methods available to a farmer, on average the cost of a single bullet for every predator killed.
- Disadvantages: It is very seldom that an experienced livestock-killer will be killed by this method. It is usually young, sub-adult predators who have not yet learned that people can be dangerous, who are most likely to be seen and killed. Like other lethal methods, it can have the opposite result with an increase in livestock predation, instead [7, 32].
- Limitations: This method has very few constraints and can be applied on almost any farm. There are evidence that at least for some predator

species, it can be counter-productive and increase livestock depredation, however.

AppendixA.1.4. Trapping
Whether with the aim of extermination of predators or just reducing predator numbers, the costs and effectiveness of trapping is more-or-less the same. Different kinds of traps are commonly used, including snares, leghold traps (gin traps), killer traps (quick kill traps / cony bear traps) and cage traps. Traps are often used together with fences to catch animals as they move through holes in the fence..

- Advantages: Some traps, including most cage traps and some kinds of leghold traps (soft traps) and even some kind of leghold snare traps, can be quite selective: while not selective in which animals they catch, when causing no permanent injury to the animal caught, a beneficial or non-target species can simply be released back into the wild. If a specific individual problem predator is responsible for all or most livestock depredation, such selection can even be at the individual level. The equipment is also fairly inexpensive and normally easy to use.

- Disadvantages: Most traps by themselves are fairly unselective. They need to be checked at least once per day in order to prevent the death or injury of non-target species. Some kinds of traps, like most snares, all killer traps and most gin traps, often cause so much injury to the caught animals, that even non-target species have to be put down after having been caught. These kinds of traps, even if checked regularly, are still unselective. Cage traps are totally ineffective against jackals, meaning that their use will result in more felid predators being killed, causing a change in the ecological equilibrium (balance) that has been formed with a resultant increase in both jackals and livestock depredation by jackals. Moreover, some species like leopards, react very aggressively to being caught in a cage trap and in the process often injure teeth or claws [54]. This decrease their hunting ability, sometimes forcing them to start killing livestock (or even humans - 4) to survive if they are released again (see section on translocation on page 52). Like other lethal methods aimed at either the extermination of predators or just a decrease in their numbers, the evidence suggest that trapping has little long-term effect on livestock depredation levels [16] and might even be counter-productive [32]. Setting and checking traps is also relatively labour intensive (*cf* 110) and many farms using this method need at least one labourer permanently employed for this purpose (Corrie van der Westhuizen 2016, personal communication). If traps are not checked regularly, it leads to the cruel deaths of many innocent or beneficial wild animals (up to 80% of the animals caught according to a CLT survey in Namaqualand; Ben-Jon Dreyer 2012, personal communication). If, as is usual, the trap is set at a hole underneath the fence, once an animals has been caught in the trap, predators can move freely through

that hole (and even scavenge on the animals already caught in the trap), making the fence useless for keeping predators away from livestock.

- Limitations: If the farm is very big, or the workforce on the farm very small, it might be impossible to check the traps regularly and their use becomes unethical. Setting traps to catch animals of the right size and without injury, require some specialist knowledge. For trapping to be really effective in either exterminating predators or decreasing livestock depredation, it really needs to be used district-wide (with other lethal methods) and are most likely to be effective in transformed landscapes with little natural habitat or prey for predators. As mentioned, some trapping methods work better against some predators while not working against other predator species at all. Black-backed jackals specifically, are notorious for being very difficult to catch, and avoiding both poison and cage traps. Even using leghold traps for catching jackals can be a challenge.

By not trying to manipulate predator numbers and allowing them to stabilize at equilibrium densities, many preventative methods can be considered as more sustainable in the long term..

AppendixA.1.5. Herding
Even before hunting (used since the Dutch came to the Cape), most of the indigenous livestock-keeping peoples used herding and kraaling to protect their livestock from depredation [123]. World-wide, herding has traditionally and almost universally included the following aspects [90]: By day the animals were allowed to graze as a herd, under the care of a herder. Livestock were prevented from spreading out, either by the herder or a herding dog. The herder directed their movement and selected the areas to be grazed during the day time. At night the flock was rounded up and either herded into a fenced area (kraal/corral/boma) or bedded under supervision in an open area where a shepherd slept near the flock. In most European and middle-Eastern regions large guarding dogs were also kept with the flocks by both day and night. Overgrazing was avoided by keeping the flocks on the move..

- Advantages: Herding with kraaling, and herding and/or guarding dogs, is still one of the most effective methods to prevent livestock depredation. Herding dogs can really make life easier for the herder.

- Disadvantages: With settled farms instead of the nomadic lifestyle of the past, the greatest disadvantage of herding when it is combined with kraaling (as it almost always is), is the resulting trampling of the veld around the kraal. Another common objection is that, especially in hot climates, the livestock are not able to graze at night. Free-ranging livestock will take advantage of the cooler nights, especially on moonlit nights, to graze during the night and rest during the heat of the day in summer. This becomes impossible when herding and kraaling, resulting in an appreciably

lower meat production (kg/ha), similar to that mentioned by Hansen [62]. Training of both herders and herding dogs: if using herding dogs, a lot of training is needed and it also takes time for a good herder to get to know the veld, good grazing areas, predation danger spots and his livestock (and dogs) well.

- Limitations: The greatest limitation on using herders, is the difficulty of finding reliable herders. In Southern Africa, it has traditionally been the job of children, resulting in it being a low-paying and low-status job on most farms. In an experiment by Conservation South Africa and Cape Leopard Trust in Namaqualand with "ecorangers" (specially trained herders who used mobile GPS devices with a CyberTracker application to record data on livestock movements, depredation losses, predator tracks etc.), out of a group of 16 who went through a process of selection, interviews and training, at the end of the research period only 8 were found to be reliable and doing a good job caring for the livestock, and only 5 said that they would consider a permanent career as ecoranger in future. It was found that one of the best incentives for a herder was owning some of the livestock (Corrie van der Westhuizen, Brenda Snyman, 2016 personal communication), something that few farmers might be willing to do [141]. Alternatively, costs for herders can be sponsored from outside (e.g. the Ecoranger project was sponsored in part by the government or the Wildlife Guardian program of Defenders of Wildlife mentioned by 148), but this is unlikely to be sustainable.

AppendixA.1.6. Patrolling to scare away predators

"Range riders" is a method introduced by Defenders of Wildlife in the USA, but based on much older principles [159]. Basically it involves using horses to ride through areas where the livestock are grazing, seeing what their health and condition are like, and using the human activity to scare predators away from the livestock. In the USA it is used for extensive farming on open range. A similar approach has been used in extensive systems in Norway using a range inspector patrolling with a livestock guarding dog (LGD)[62]. Because of the resistance by some farmers against kraaling their livestock at night, the research project in Namaqualand by the Cape Leopard Trust (CLT) and Conservation South Africa (CSA) also used some of their Eco-Rangers in the same way to patrol the camp where the livestock were with the dog to scare away predators through their presence..

- Advantages: This method is well suited to more extensive farming systems, where daily kraaling is not practical. In these kind of systems the livestock is seen more frequently and any non-predator related problems and general veld condition are also picked up earlier than would be otherwise the case. Spoor tracking also gives an idea about where the predators spend most of their time and from where livestock should be moved for their own safety. Where the livestock breeds do not have a strong natural herding

instinct or are forced to scatter to find enough grazing, this is one of the few methods that can still reduce livestock depredation. If horses are not used, the costs of this method is about the same as that of a herder (and dog), but has the advantage that the dog does not have to first bond with the livestock and that the livestock can graze at night and thus grow and reproduce better.

- Disadvantages: Because most predators hunt at night when human presence are less likely to have an effect, this method is not very effective. Even Stone et al. [159] had to admit that there was no direct proof yet "that range riders actually prevented livestock losses from predators". Labour is a fast growing cost; rangers that can ride horses plus the necessary horse-riding equipment (saddles, bridles etc.) can be quite expensive.
- Limitations: This method is more likely to work in flat open areas and not a good fit for thick bush or rough, mountainous farms. It is only likely to be worth the expense if livestock losses are relatively high, unless the farmer already have horses, riding gear, and labourers that can ride.

AppendixA.1.7. Kraaling at night
Kraaling involves the practice of having livestock sleep in an enclosure (called a kraal, corral, pen, or boma, depending on geographical part of the world) at night, when most predators are active. These enclosures are usually made predator-proof in some way [123, 177]. Begg and Kushnir [14] list a number of different kraal types that will protect against lions, including traditional Acacia thorn kraals, stone kraals, chain linked fence kraals, "living wall bomas" [83], mobile kraals and small log pens for kids or lambs..

- Advantages: Kraaling, combined with herding or guard animals, are often the only option where there are high numbers of predators. Kraaling can be used on its own with the kraal built around water troughs and kept closed while the livestock are out grazing, only opened when they are let into the kraal at nightfall. When combined with guarding dogs sleeping inside the kraal, it is one of the most effective ways for keeping depredation low at night. Costs for building kraals can vary between only labour and time for traditional thorn bush (high maintenance) and stone kraals (almost no maintenance) to US$200.00 - US$900.00 for a chain link fence, an average of US$ 500.00 for the living wall bomas (almost no maintenance) and about US$2000.00 for a mobile kraal [14].
- Disadvantages: The greatest single objection to kraaling, is the trampling of the veld that usually happens around the kraal. If there are water available in pans or wetlands during the rainy seasons, some livestock might also not come to drink water at the kraal and thus sleep outside and remain vulnerable to depredation, when kraaling is not combined with herding. Another important draw-back is the built-up of parasites and outbreaks of disease, which are much more likely to happen in the crowded situation and repeated use of the same area, typical of kraaling.

- Limitations: Different levels of predator proofing are effective against different predators. Jackal-proof fences are easy for caracals and leopards to climb and might cause very high surplus killing if one of these species get inside the kraal. Moreover, the kraal obviously has to be strong enough to keep the livestock inside as well (e.g. fighting bulls or frightened cattle might break out of an enclosure that is not strong enough). While some of the veld trampling can be avoided by using mobile kraals that are moved every now and then, these mobile kraals are often insufficient to keep predators out. Additionally, with many different flocks in different camps, this method can be quite labour-intensive and impractical on large, extensive or mountainous farms where reaching the furthest camps can take many hours.

AppendixA.1.8. Carnivore-proof fencing for eradication of predators
In Southern Africa, jackal-proof fencing was first introduced in the early 1900's and became compulsory in the sheep-producing areas [17]. By government subsidising jackal-proof fencing, combined with setting up various hunting clubs, the attempt at eradication of black-backed jackals finally succeeded in some districts [15] to the extent that by 1967 the government felt that predators were relatively under control and no longer needed direct government involvement [17]. A totally predator-proof fence is possible, but very expensive, and only really economically viable for small breeding camps of high-value game species, like sable and roan (W.P. Barnard 2015, personal communication). Predators are not killed by the fence itself, but by constricting the movement of predators within the camp and clearing the camps from predators one by one using other methods, it can result in an almost total eradication of the predators in a whole district. As the other side of eradicating predators on farmlands, Packer et al. [125] proposed the use of carnivore-proof fencing to keep large predators within protected areas, as the most cost-effective method of protecting predators, lions in particular [126]. This is basically an application of the zoning approach proposed by Linnell et al. [90][148]..

- Advantages: For almost total eradication of predators, this is one of the only methods that have proved to be successful against black-backed jackal in some areas.

- Disadvantages: Putting up predator-proof fencing, especially without any government subsidies, is very expensive. Predator-proof fencing do not only stop predators, but also most other wildlife from freely moving around. This has a negative effect on the overall biodiversity of the veld and its long-term sustainability. Because digging animals like warthogs and aardvarks often dig underneath fences, it is important to regularly patrol and maintain all fences, if the fences are to be effective at all. This can be quite expensive and labour-intensive and with the typical increase in labour costs, no government subsidising and low profit margins of livestock farming, makes it more expensive and less effective than alternatives. Once

the predator is inside the camp it can kill prey (including livestock) easier by cornering them against the fence, often leading to surplus killing. This is a disadvantage of all kinds of fences, including kraals.

- Limitations: Truly predator-proof fencing is not possible in some kinds of terrain, like very mountainous habitats. Jackal-proof fencing, while relatively effective against jackals, are not effective at all against caracals and leopards, so only really effective when jackals are the only significant predator species. The high costs of proper predator-proof fencing, the age and state of disrepair of current fences, the lack of government subsidies, and the lack of district-wide cooperation makes it increasingly impractical for your typical livestock farmer. The increase in "week-end" farmers with less time to spend on maintenance, makes any district-wide attempts at predator eradication impractical. The fall in profitability of farms per hectares, resulting in fewer farmers and larger farms to remain economically viable [119], also makes maintenance of fences more difficult. Linnell et al. [90] concluded that fencing is only really practical to keep predators out of specific, relatively small, grazing pastures (discussed further below on page 38).

AppendixA.1.9. Electric fencing

Electric fencing can be used either as a kind of predator-proof fencing or as mobile, temporary fencing, primarily for livestock (usually as part of holistic short-duration high-intensity grazing systems). For mobile electronic fences, a single strand is often used to keep the livestock together and while it might not keep the predators out, by keeping the livestock together, it effectively causes the livestock to use other methods against predators (like cattle protecting small livestock and keeping livestock bunched together for protection). Stone et al. [159] showed that combining electric fencing with fladry (a series of red or orange cloth flags hung at 45 cm intervals along a thin rope) can have better results than either on its own. Paine [127] describe how to install various kinds of electric fencing in more detail..

- Advantages: Electric fences can keep out predators like caracals and leopards as well as jackals, if high enough and properly done. It can also prevent digging animals like aardvark or warthogs from making openings below the fences that predators can use to move through. Mobile electric fencing can be used as a management tool for short-duration, high-intensity grazing systems ("holistic grazing") without being nearly as labour-intensive as normal herding. It can be a very effective method to keep predators away from a relatively small area.

- Disadvantages: Electric fencing is quite a bit more expensive than other fencing and requires a lot more maintenance as well. Additionally, it does not work in all kinds of terrain, especially not in high or bushy vegetation. It also has a negative effect on ecology, biodiversity and sustainability

by stopping the movement of all wildlife and often killing innocent or beneficial animals [93].

- Limitations: Because it is so expensive, electric fencing is not an option for fencing whole districts. Even just a whole farm will be too expensive for a typical livestock farmer to afford, especially in areas with low economic or ecological [29] carrying capacity.

AppendixA.1.10. Static visual and acoustic predator repellents
These kinds of repellents are normally used for relatively small areas in the farm, e.g. calving or lambing camps, with especially vulnerable livestock. According to Hunt [70], deterrents are meant to discourage the presence of a predator in a certain area before conflict occur, repellents are meant to discourage specific behaviour of a predator in certain area and are usually human-triggered, while aversive conditioning is meant to modify previously undesirable behaviour. Shivik et al. [150] differentiated between primary repellents that depend on novelty (neophobia), irritation or pain to stop a predator from some behaviour and secondary repellents that depend on previously learned predator behaviour to prevent some behaviour. Linnell et al. [90] discuss some of the visual and acoustic repellent as well as their effectiveness for keeping coyotes away from sheep. It included a gas "exploder" used at night and 3 different strobe light and siren devices. Known as RAG (radio activated guard) devices in the USA, some units only activate when collared predators come near to them [159]. These units cost about US$ 3000 per unit [149]. In Southern Africa the "Jakkalsjaer" is the most commonly available model (`http://www.pmfsa.co.za/home/contact-us/predation-management-experts-equipment`) which also include the sound of a radio station in addition to sirens and lights. The costs (in 2008) were between N$ 1550.00 and N$ 1950.00 per unit. A variation on this method has been used recently around Cape Town to keep baboons away from residential areas and prevent conflict with people. A simple timed propane cannon has been used in Namaqualand, Northern Cape, South Africa to scare baboons away from a kraal with young goat kids (personal observation). In the USA fladry, in which flags hang from ropes stretched a short distance above the ground and costing about US$ 781.00 per km [149], is frequently used as a mobile repellent against wolves [127]. Combined with an electrical line (turbofladry), it costs about US$ 1328 per km [149]..

- Advantages: These repellents are usually easy to set up, not labour intensive and relatively cheap to maintain [148]. While seldom 100% effective for long, it has been reported to cause a 60% reduction in livestock losses over one season [90]. "Lion lights" in Kenya has had a 100% effectiveness in keeping lions from killing cattle in an enclosure at night [69] (so far) by mimicking people walking around with flash-lights at night. Stone et al. [159] mentioned that when fladry is combined with (temporary) electric fencing it worked well, repelling wolves even when the fence was temporarily not electrified. This combination, known as turbofladry, might work

well for other predators as well, by combining a very visual signal with a real painful stimulus, and work better than either the electric fence or the fladry on its own.

- Disadvantages: The greatest disadvantage is that like most repellents, predators can get used to them making them ineffectual, so it is almost always a temporary solution. In the cases mentioned by Linnell et al. [90], they succeeded in keeping coyotes away for between 1 and 180 days. They conclude that these methods are not really effective for longer periods of time. The explosive repellents have been found to be effective against coyotes for an average of 31 days [90]. Fladry also worked only for up to 60 days against wolves [117]. Fladry, while cheaper than the other options, is also maintenance-intensive. The Jakkalsjaer repellents also only have a limited range (about 150 ha per unit) and while livestock in a camp that is close to it might be save, others that are further away in a camp, might still be vulnerable (or multiple devices per camp might be needed). Moreover, sometimes the lights and sounds attract thieves who steal not only the livestock, but also the expensive equipment [93]. Most predators are territorial. If there are repellents in all of its territory, hunger will force the predator to habituate to the repellents eventually. Therefore it is important that the predators have "sanctuaries" without any livestock and where they can survive on wild prey, for this method to be effective.

- Limitations: These kinds of methods are really only useful for keeping predators away from small pasture camps or kraals. So far, fladry is not known to work against any other mammals except wolves [117]. It appears to work for longer when the repellent mimics a real danger (e.g. people walking with flash-lights at night). Because predators get used to the unusual lights or sounds, Linnell et al. [90] recommend that it only be used for relatively short periods when livestock are especially vulnerable.

AppendixA.1.11. Predator repellent collars on livestock
These kind of repellents are usually affixed to the livestock with a collar. They vary in kind from age-old low-tech bell collars to modern high-tech E-shepherd collars (`http://eshepherd.biz/faq.html`). They vary greatly in price and effectiveness, but they all contribute to the ability of predators to distinguish between natural prey and livestock [89]. The e-shepherd is a system where the collar gives an ultrasound alarm and shine LED lights as soon as the sheep starts running (being chased by a predators) or leave a certain area. Another high-tech type collar is the GSM based "Veldwagter" system [91]. .

- Advantages: For the high-tech versions which only gives an alarm when the livestock are being attacked, it takes longer for the predators to get used to them. Preliminary testing of the E-Shepherd collars have shown them to be effective for at least a year. This implies that while predators might eventually get used to them, they are effective for longer periods than the static repellents. They can also be used together with other

methods (e.g. livestock guarding dogs with bell collars) to warn predators away. The "Veldwagter" system has also helped to prevent stock theft [152], another major source of livestock losses in parts of Southern Africa. In the best case so far, it has reduced livestock losses from 320 sheep per year down to 12 sheep per year. It appears to be a good choice for farms close to towns where cell phone coverage is better and the more likely causes of livestock loss are theft and domestic feral dogs. Bell collars work well together with herders and LGDs, both in warning the predator that livestock are not natural prey, and in helping the herder to locate and keep the herd together [14].

- Disadvantage: Once predators have habituated to the repellent, it can have exactly the opposite effect of calling the predator to dinner, rather than warning the predator off. And predators learn from each other, so this behaviour might spread quite quickly within the predator population once a single predator has figured out that the collars are actually harmless. The high-tech versions of the collars are quite expensive. The E-shepherd collars costing about the same as a fully-grown sheep (N$ 1200.00 in the beginning of 2016 - E-Shepherd, personal communication). It is recommended that at least one collar per every 10 sheep be used, meaning that depredation losses must be very high before it begins to make economic sense. The "Veldwagter"system [152] uses the cell phone network to warn the farmer of any unusual movement of sheep. It costs almost N$ 5000.00 per collar (in 2008) and therefore only one collar per herd is recommended, meaning that if the herd breaks up into smaller groups (like Dorper sheep and many European breeds), it might no longer be effective. Like any other collaring system, this method is quite labour-intensive, especially when collars are using on growing lambs or kids (the most vulnerable individuals), since the collars have to be checked and adjusted every couple of weeks. In extensive farming systems where livestock are not seen regularly, the collar might start to strangle growing sub-adults (Charles Schreuder 2011, personal communication).
- Limitations: All these methods will only be effective in the long run if there is enough wild prey available to the predators as an alternative food source (or the neighbour's livestock when he is doing less to protect his livestock). If there is no other option, hunger will force the predator to attack livestock in spite of the repellent collars. The high cost versions are only an option in cases of very high livestock depredation rates, while the low cost versions are only effective (if at all) in combination with other methods. It is also not a good option for extensive farming systems which aim to be less labour intensive. Some systems (e.g. the Veldwagter collars) require cell phone coverage to work, making it impractical for large parts of Namibia.

Collars that give wolves an electric shock when coming close to a homestead have also been tested in the past (e.g. 159). Unlike conditioned taste aversion (CTA,

see page 29) the behaviour change did not last long. A number of factors make this method impractical... Unless a single animal is causing all the damage and it is being used as reactive method, this method cannot be used. It can help to keep the predator away from a certain area, but will not prevent the predator from killing livestock elsewhere. All vulnerable livestock therefore need to be kept inside the "protected" area that will cause the collar to shock the predator. The period of effectiveness will be restricted pretty much to the shock collar's battery life. The difficulty in capturing the right individual causing the livestock depredation plus the collaring cost, limits it usefulness further. It will thus not be discussed further here..

AppendixA.1.12. Protective livestock collars
In contrast to poison collars (a reactive measure) where the livestock animal with the collar is sacrificed in the process, these collars attempt to prevent the predator from killing livestock. It also differs from the repellent types of collars by not primarily trying to change the predator behaviour, but to make actual attacks less effective, instead. Most predators attack the neck or throat to kill livestock. These kind of collars thus aim to prevent a predator attack from succeeding in killing the livestock animal, but also hope to change predator behaviour to avoid livestock and revert to natural prey instead. The most commonly available versions in Southern Africa, are the KingCollar (a broad, 1 mm thick, semi-rigid, high-density polyethylene collar that are attached to the entire flock of livestock) and the Dead Stop Collars (consisting of a broad metal mesh, which is epoxy-coated), both described in Smuts [152]..

- Advantages: In a cost-benefit study in the Eastern Cape Karoo, McManus et al. [110] showed that Dead Stop Collars decreased costs and livestock losses significantly compared to trapping and hunting and did not differ significantly from the use of livestock guarding animals (dogs and alpacas).

- Disadvantages: Like all collars, the use of the Dead Stop Collars [152] (cost: just over N$20.00/collar in 2008) or KingCollars [80] (cost: N$ 5.00-6.00 depending on size in 2008) can kill livestock by strangulation if not checked and adjusted regularly on growing livestock (Charles Schreuder 2011, personal communication). It is thus fairly labour intensive. To be truly effective, every single vulnerable livestock animals needs to be collared, since the aim of this method is not primarily to change predator behaviour. However, it can have a negative backlash when some predators (especially jackals) start to attack livestock from behind by ripping them apart and avoiding the neck or throat when attacking.

- Limitations: The greatest limitation of these collars are that applying them can be fairly labour-intensive. In general, they are more effective against felid predators than against canids or hyaenas. There need to be enough alternative prey for predators, otherwise they can change their attack method to avoid the neck and throat of livestock [152]. This might be the explanation for the fact that in the McManus et al. [110] study, the

only two farmers who had a slight (though not statistically significant) increase in depredation in the second year of using non-lethal methods, were those who only used protective livestock collars.

AppendixA.1.13. Carcass disposal
By preventing carnivores from eating livestock carcasses, it decreases the probability of the them learning to consider livestock as a food source [46]. It can also help to prevent predator numbers from growing, by not providing them with extra free food [90]. Most predators will scavenge when the opportunity presents itself, although some species, like cheetahs, almost never scavenge and will often not even return to the remains of their own kills. Lamb tails when they are removed, or even the afterbirth of livestock, should be removed from the veld and burnt, for the same reasons [35]. It is a good idea to have a predator-proof fenced carcass pit where any livestock carcasses or remains are burnt [159]..

- Advantages: While very unlikely to have a large effect on livestock losses due to depredation, this method is easy to use together with most other methods. It is aimed at changing predator behaviour (or rather to prevent certain learned predator behaviour), rather than directly preventing livestock depredation. Because it encourages natural predator behaviour by teaching predators not to consider livestock as natural prey, it is ecologically sustainable.

- Disadvantages: On its own, this method has almost no effect on livestock depredation. If the carcasses of livestock that died from natural causes are the only food available, getting rid of it might encourage predators to kill livestock instead for food. Finding and getting rid of all livestock carcasses on a large farm might be almost impossible and even on smaller farms with many areas impassable by vehicles, it might be very difficult to find all livestock carcasses [148].

- Limitations: This method does not work at all for those predators (like cheetahs) that do not scavenge.

AppendixA.1.14. Food aversion conditioning of predators
Conditioned taste aversion (CTA) was already discovered as a unique kind of learning by Garcia et al. [55] and first demonstrated as a possible method to decrease livestock depredation by Gustavson et al. [58]. Like the static or mobile repellent methods, the aim is to change predator behaviour [90, 166, 148]. The most common chemical used for this purpose is lithium chloride (LiCl) (e.g. 58) but other emetic compounds used include cupric sulphate (CuSO4), emetine hydrochloride (EHCl), alpha-naphthyl-thiourea (ANTU) [90], anthelmintic thiabendazole (TBZ) [41], and Ziram [8]. CTA is based on the same principle exploited by organisms using Batesian mimicry, where even a single event of a predator eating some prey causing them to be sick, can cause a prolonged aversion to similar prey animals [52]. This method has been less successful in field trials [57, 87], mostly because it depends on the predators not tasting the

chemical (LiCl) and thus not being able to differentiate it from the known taste of livestock meat [53, 52]. Because precise dosages, well distributed through the livestock carcasses are required [52], farmers do not always implement it correctly resulting in failure [46]..

- Advantages: This methods is inexpensive. In contrast to poisons, it is safe for humans and non-lethal to predators, scavengers and secondary consumers (no negative environmental impact). As long as the territorial predators with a developed taste aversion stay in their territories, its effect is relatively long-lasting. It can be combined easily with most husbandry methods. Trained territorial predators "protect" livestock from other predators, so once taste aversion has been established, it is not very labour-intensive to maintain [52].

- Disadvantages: The taste is specific to a specific livestock type. In other words, if predators develop a taste aversion to sheep, they might still kill cattle and goats. The greatest disadvantage is probably the logistical issues [46, 87]. Finding all or most livestock carcasses to treat or enough bait so that all residential predators develop an aversion to the taste of all livestock species, is difficult, and may be impossible. As a method, it is highly sensitive to methodological variation [46]. Moreover, it does not work overnight, so farmers might loose a number of livestock before predators starts to avoid killing livestock. Misapplication is not neutral in the sense that it can actually increase depredation losses if done wrongly, e.g. if the predator learn to taste the chemical and start killing livestock (which will always be untreated) while avoiding treated carcasses. Because it depend on resident predators learning to avoid killing livestock, it is incompatible with any method that involves predator removal [52].

- Limitations: If the findings for coyotes as reported by Jaeger [72] are also true for black-backed jackals, and alpha breeding pairs are the real killers of livestock while the betas and transients are mostly scavengers, this method will not work since the livestock killers will never be able to develop a taste aversion. And of course, it will be useless against predators like cheetahs that do not normally scavenge and are thus unlikely to ever take any bait. A taste aversion to livestock carcasses does not necessarily result in predators not killing livestock [87, 150]. Baker et al. [8] showed that the same chemical have different effects on different predator species. Since eating any untreated livestock meat will cause any previous conditioned aversion to stop, the only situation where this method is an option is where it can be ensured that all livestock carcasses on the farm have been treated. This method thus has to be combined with carcass disposal and share all its disadvantages and limitations as well.

AppendixA.1.15. Chemical predator repellents
Various chemical repellents have been tested against predators. In contrast to conditioned taste aversion (CTA), it does not work by causing nausea and

vomiting in predators as a means of teaching them to avoid livestock. Instead, strong-tasting chemicals like capsaicin (the active ingredient of red peppers), undecenovanillylamide (nor-capsaicin), cinnamaldehyde or various commercial products are put on foods to stop animals from eating it. It has worked with vegetative foods [90], but little success has been demonstrated against predators except as a repellent when threatening humans [70]..

- Advantages: Unlike CTA that takes a while to have any effect, if it works as a repellent, it would stop predators from killing livestock immediately.

- Disadvantages: While some success has been shown against some predators, other predators have change their attack methods, similar to what happens against protective livestock collars [90]. This method does not work for all or even most predators. Putting repellents on all vulnerable livestock is labour-intensive. One if the greatest drawbacks of this method is that it is not predator-selective, but also affect livestock and humans [148].

- Limitations: If used together with livestock protective collars on the hindquarters of livestock, this method have some potential, but this has not been demonstrated as effective in lowering livestock depredation, yet. When used in collars, it has been demonstrated as ineffective and teaching the predators to attack the hindquarters instead of the neck (Burns and Mason, 1996, quoted in 148). In addition the fact that it is labour-intensive makes it unsuitable for extensive types of farming.

AppendixA.1.16. Projectile predator repellents

This method involves shooting predators with projectiles (e.g. rubber bullets or paint balls) to chase them away from livestock [90]. It is usually use in combination with other methods like calving or lambing camps in order to keep predators away from a specific area. It has been shown that predators do not necessarily associate the repellents with livestock or the area, but rather with the person(s) shooting at them [148, 149]. It can also be used by herders and patrolling range riders to scare away predators from the vicinity of livestock herds [159]..

- Advantages: For predators that have become very used to people and attack livestock close to farm homesteads, this can be an easy and non-lethal method to chase them away. It also combines quite naturally with patrolling of areas where livestock are grazing and can thus be used in different ways to both intensive and extensive farming.

- Disadvantages: Because predators might not associate the repellent with livestock or the area around the homestead, they might simply become better at avoiding people who might shoot at them while continuing to kill livestock.

- Limitations: This method is very unlikely to work for predators that hunt at night (most Southern African predators). Unless the farmer catch the predators in the act of hunting livestock, this method is pretty much useless.

AppendixA.1.17. Natural repellents
Predators mark their territories to warn away other predators, both conspecifics and competing predator species. Jackals and caracals are known to kill each other's young [20, 42] and probably show habitat partition and niche contraction when sharing an area. Leopards kill other predators, including cheetahs, caracals and jackals and these predators might want to avoid leopards or experience a decrease in their numbers when there are leopards around [137]. The importance of such predator interactions is illustrated by Bothma [20], "The average carnivore in Africa is prone to predation and ecological influence from 15 other types of carnivore at some stage of its life". On an Eastern Cape farm where jackals used to be a major cause of livestock loss, caracals has been used successfully for years to decrease the losses (66, `http://www.farmersweekly.co.za/article.aspx?id=286`; Du Toit [42], `http://karoospace.co.za/can-caracals-save-sheep` last accessed 15 February 2017). After initially releasing some caracals on the land to they put caracal scat around kraals and lambing camps to keep jackals away from the sheep. .

- Advantages: Unlike many human-made repellents that depend on the wariness of predators towards the unknown, because these kind of repellents are backed by the actual threat of inter-specific violent interactions [137], they remain effective for periods of up to 10 years so far (Marion Holmes, personal communication).

- Disadvantages: Because the method works on the principle of establishing a fake predator territory around the area where the livestock will be, it can only be used to protect a certain relatively small area. Finding enough faeces to implement this method might be impossible without captive predators to provide scat (e.g. wildlife rehabilitation centres). Because the scat are strewn twice weekly, it can be quite labour intensive. Too little research has been done on the interactions between all Southern African predators to know when and how effective this method will be in difference situations [27, 33, 43, 64, 74, 75, 76, 113, 137].

- Limitations: This method is not compatible with lethal methods or other methods that disturb the territorial distribution of predators on the farm.

AppendixA.1.18. Increasing natural prey
A study in the 1990's by Marker et al. [105] in North Central Namibia, found that the only factor to make a significant difference in the levels of livestock depredation, was the number of wild prey on the farm (see also 5). For many of the other methods to work at all, there needs to be an alternative source of prey available to predators. Cheetah [107] and leopard [115] take livestock in lower

numbers than what would be expected from livestock stocking rates if they simply took prey according to availability. Khorozyan et al. [79] showed that definite densities of wildlife exist, below which predators will switch from wild prey to livestock..

- Advantages: Especially in Northern Namibia, but also in other parts of Southern Africa, this method costs almost nothing except hunting less game and limiting hunting dogs on farms. It combines well with most other methods and increases the biodiversity and thus ecological stability of the land.

- Disadvantages: Where there is no or few game currently, it can be expensive to reintroduce wildlife on farms. Even where some original wildlife can still be found on a farm, it can take a while before game numbers reach high enough numbers to make a difference in livestock losses. In many cases an increase in natural prey numbers will not be sufficient to decrease livestock losses.

- Limitations: This method is not really an option in transformed landscapes where little natural habitat remains for wildlife. In some areas where the total sustainable stocking rate for all herbivores is below the critical density found by Khorozyan et al., this method might also not be an option.

AppendixA.1.19. Livestock guarding dogs (LGDs)
Livestock guarding dogs are already mentioned in one of the oldest books in the Bible (Job 30:1). Livestock guarding dogs should be clearly distinguished from herding dogs. Whereas herding dogs use behaviour similar to that of a predator to scare and bunch livestock together and move them in the direction they want, livestock guarding dogs behave as one of the flock. They are bred to be trustworthy (will not harm the flock), attentive (stays with the flock), and protective (barks and defends the flock). One of the best adapted breeds to the Namibian climate, long distances and large enough for its predator species, is the Anatolian/Kangal, although Rhodesian Ridgebacks have also been used with success (90, 2, 168, 169, 170). While there are many other breeds of livestock guarding dogs that are protective, attentive and trustworthy, most of them were bred for different climates and are not a good fit for the heat and long daily livestock movements of Namibia. LGDs are used in different ways. The traditional way and the most effective [62], is the use of dogs together with herders and kraaling at night. But they have also been used in other ways, some of which are better suited to extensive farming conditions: the cheapest method (and the second most effective) is having LGDs alone in camps with livestock. Two other options is having LGDs alone with livestock in open range [170] or patrolling the livestock together with a "range inspector" [62]. An evaluation of various livestock guarding dogs in Slovakia, showed that the success of dogs depended more on the attitude and diligence of the herders than on the breed of dog [135]..

- Advantages: Well-trained livestock guarding dogs are one the best protectors of livestock against predators [100]. Compared to herders, they are also relatively cheap (the cost of the puppy plus about N$500.00/month for food and veterinary costs = cost of 5-6 small livestock units saved per year). Once the dog and livestock have bonded, self-feeders can be used to feed them and a minimum of effort and labour is required for maintaining the protection of livestock (Ivan van Niekerk 2016, personal communication).
- Disadvantages: It takes about a year for an Anatolian shepherd dog to be trained and develop enough confidence to chase away a large predator like a leopard or cheetahs. Therefore in the first year of its life, a livestock guarding dog needs to be accompanied by a herder in order to teach it not to chase game, play with the young livestock or learn other behavioural problems. Of course, the herd itself also needs to be protected until the LGD can take its place. For this reason, the first year of the dog's training can be quite expensive. On average a LGD has a working lifetime of about 4-5 years in Namibia and sometimes a dog can die from snake bite within its first year of working [101]. However, since snakebite have been the major cause of death, snake aversion training might extend the average working life of LGDs [142]. This means that a new dog needs to be trained on average every 5 year just to protect the same number of livestock. If a LGD is not trained properly, it can show all kinds of behavioural problems, including at worst, starting to kill livestock itself. Therefore the herder doing the training needs both to know how to train the dog and be trustworthy [146, 129]. Another major drawback to using LDGs, is that the demand is much higher than the supply, so a farmer might not always be able get a dog when required. Although self-feeders can ease the problem, regular care of the dog is still a requirement making the utilization of remote areas by livestock problematic. Sometimes the most vulnerable livestock is no longer in the herd to which the LGD has bonded and a whole process is involved to introduce the dog to its new herd. This method can thus cause a lot more management headaches compared to other methods.
- Limitations: One LGD can protect no more than 200 small livestock effectively. This will also depend on the vegetation, terrain and the predator threat itself. Because the dogs bond with a specific herd, when two herds each with their own LGD are put into adjacent camps, the dog might attack each other, attack the livestock of the neighbouring camp or even start to spend time with each other and start ignoring the livestock. LGDs have not been tested with cattle, but it will probably be quite difficult to bond the dog with cattle, since most cows will tend to be quite aggressive in protecting their calves and can easily kill the puppy. So while it might be possible, bonding cattle and dogs has not yet been tested. Not only does the dog need to bond with the livestock herd, but the herd also needs to bond with the dog. When this does not happen properly, some sheep

will run away from the dog and can even break legs or kill themselves while running away from the dog, especially in mountainous terrain (personal observation). The dog is also limited to work only with the kind of livestock to which it is bonded, meaning that a dog that was raised with goats cannot be used with sheep, nor a dog raised with sheep used with goats.

AppendixA.1.20. Guard donkeys

Donkeys are one of the undervalued protection animals against predators. While they cannot protect against some of the same size predators that LGDs can, they do not require special feeding, as they graze with the other livestock and are much easier and cheaper to acquire [90]. The principle behind this method is to use the protective instinct of a donkey for her foal to also protect other livestock. Normally a female donkey that has recently foaled is put with her foal among livestock about to calf. Since she would not like to be alone, she tends to stay with the livestock and chase away any predators that threaten the young. To be successfully implemented, there are a number of guidelines to keep in mind: 1) use only a mare or gelding since donkey stallions can be aggressive to livestock; 2) have the donkey bond with the herd it is to protect for 4-6 weeks; 3) use only one donkey per herd, (or a single jenny with a foal), otherwise a group of donkey will rather graze on their own; 4) test a new donkey's response to predators (use a dog in a kraal with the donkey and do not use donkeys that react passively); and 5) use donkeys in small open pastures with a moderate-size herd [98]. .

- Advantages: Using donkeys are faster to implement than livestock guarding dogs (LGDs) with no need for training. They are cheap to buy and maintain, since they live on the same grazing as the other livestock. They have a longer life expectancy than LGDs (10-20 years), and can be used in combination with many other methods [90].

- Disadvantages: Donkeys are reportedly less effective in preventing livestock losses than livestock guarding dogs [90].

- Limitations: While donkeys are fairly effective against cheetahs and smaller predators, leopards and larger predators are not discouraged by donkeys and would sometimes go past calves in order to kill and eat a donkey foal (Francois Kok 2014, personal communication). For best results, the mare should have a foal a few weeks before the calving/lambing seasons of the livestock to be protected. This necessitates the use of seasonal breeding (see page 37).

AppendixA.1.21. Guard Llamas/Alpacas

Both llamas and alpacas are natives of South America and can used as guarding animals, but reports from Israel imply that llamas are more aggressive towards predators than alpacas [90]. These animals are basically defending their territories when they attack predators..

- Advantages: Like donkeys, they do not need to be trained or fed specifically, but graze with other livestock. Unlike donkeys, they appear to form strong bonds with the livestock they protect, especially being protective of small lambs.

- Disadvantages: Llamas are even more scarce and expensive to buy than livestock guarding dogs in Southern Africa. How well they are adapted to savannah bush vegetation is not known yet.

- Limitations: Even though they are aggressive towards smaller predators, in South America they are known to run away from pumas, so their use are probably restricted to protecting against smaller predators like caracals and jackals. Because they are territorial animals, they will probably also work better in smaller camps.

AppendixA.1.22. Protection cattle
Cattle can be used to protect small livestock from predators by the different livestock species bonding with each other. Sheep are bonded with cattle by putting lambs 45-90 days of age, with the cattle in a kraal for 60 days [90]. Goats appear not to bond directly with the cattle, but bond with sheep who in turn are bonded with cattle..

- Advantages: For predators that can be chased away by cattle, this method is apparently very effective. It can also be used very effectively together with other livestock management techniques like holistic (high-intensity, short duration) grazing and result in better veld utilization by encouraging grazing succession [172, 59]. The reduction in losses, predator-proof fence maintenance needed, and time spent searching for sheep, probably make up for the relatively high costs of the method (a similar period of bonding is required for other methods using guarding animals).

- Disadvantages: The greatest disadvantage to this method is the time and money spent during the period of bonding (US$ 0.51/lamb/day according to 90). In Namibia, where feed is relatively expensive, this cost might be even higher.

- Limitations: This method is unlikely to work against some cattle-killing predators, although not dehorning cattle is likely to have an impact even on losses due to larger predators.

AppendixA.1.23. Avoiding depredation hotspots
Predators often prefer to hunt in certain types of habitat within their home ranges [1]. This terrain in which predators prefers to hunt is determined to a large extent by their way of hunting, e.g. an ambush predator would prefer areas with enough cover for hiding and stalking while both coursing and speed hunters can be expected to prefer relatively flat areas rather than rocky or mountainous terrain for hunting. It is known that leopards avoid open areas [108],

and this has been used to decrease leopard predation on calves by keeping cows with calves away from bushy, mountainous parts of a farm (while utilizing those areas by larger oxen and cows with horns; e.g. see Landbouweekblad, 24 Junie 2011). Balme et al. [10] showed that leopards actually preferred to hunt in areas of intermediate cover, but also that the habitat type was more important than the prey species abundance. Eaton [45] showed that for cheetah in a heterogeneous environment, the hunting technique and preferred hunting areas and prey differed between different cheetah groups. However, in general, it does appear as if bush edges next to open areas are preferred cheetah hunting habitat [112]. Females normally don't move very far once they have small young, thus creating a temporary depredation hotspot around their denning sites, to be avoided by vulnerable livestock. For the smaller meso-predators, like jackals and caracals, little is known about their habitat preferences in general and their preferred hunting habitat in particular. .

- Advantages: Where livestock are kept in camps, like almost all commercial farms in Namibia, it is a very easy to implement method, costing almost nothing except planning. Because of a minimum interference with the ecology and behaviour of predators, this method "works with nature" and is one of the more sustainable methods. It can also be combined with most other methods.

- Disadvantages: This method is dependent on the veld of a farm providing heterogeneous habitat with different hunting preferences by predators. If all of the farm consists of "difficult terrain", as sometimes happens, it cannot be implemented. This might be one reason for the often reported differences in livestock depredation rates, being very high on some farms while many of the other farms in a district have negligible losses.

- Limitations: This method is only likely to work if there are disproportionate livestock losses in some areas of the farm. In general, more research about the spatial behaviour of economically significant predators is needed for this option to work well.

AppendixA.1.24. Seasonal avoidance of predation (seasonal breeding)
While the previous method depend on spatial avoidance of predators, this method depends on temporal avoidance. By having specific calving/lambing seasons, the same strategy used by many natural prey species is mimicked. By not providing the predators with a ready source of food throughout the year, an increase in predator densities is avoided. Any of the other preventative methods could also be used for a short period in those seasons when livestock are most vulnerable (e.g. when there are young animals). Such seasonal changes will need to take into account both the seasonal behaviour of the predators (e.g. breeding seasons etc. 148) and the seasonal grazing requirements of the livestock. Linnell et al. [90] summarize this method as using 1) seasonal changes in livestock husbandry practices, 2) seasonal changes in the life cycle of livestock (birth seasons), 3)

seasonal changes in predator life cycles, 4) seasonal changes in the availability of alternative prey and 5) seasonal changes in predation levels..

- Advantages: If the birth season is synchronized with that of preferred wild prey species, it can drastically reduce livestock losses compared to livestock giving birth throughout the year. Alternatively, if the predator species on a farm have a distinct breeding season (e.g. black-backed jackals in springtime) during which they would have utilized the birthing season of their natural prey in the wild to feed their young, avoiding this season for the birth of livestock can make a big difference on livestock depredation losses. Many livestock species have a natural breeding season in any case and manipulating this a bit is easy and cheap. This method can also be combined with many other methods and is almost required for some other methods to work.

- Disadvantages: There is a reason why natural prey species have their young in a specific season (when they have seasonal breeding)... it is usually the season with the best veld for raising young. This is also true for livestock. So changing the birth season to avoid predators might result in losses due to unsuitable veld conditions. Having distinct breeding seasons requires more direct management of the livestock and possibly higher labour costs. One of the greatest drawbacks is that it might result in lower birth percentages for livestock, especially in extensive farming systems where the males might simply not get to all the receptive females in time for those livestock species who are not naturally seasonal breeders, while year-round breeding increases the chance of higher birth percentages in extensive farming systems.

- Limitations: Where livestock depredation do not have seasonal peaks or does not happen primarily to feed predator young, this method is impractical. When aiming for a birth season to coincide with an increased availability of natural prey, this method is only practical where enough wild prey is available on the farm.

AppendixA.1.25. Calving or lambing camps
If possible, having safe areas for the vulnerable livestock, like young animals, is good management practice. In higher rainfall areas, such camps can be irrigated or cultivated with high-quality grazing. This is not an option in most of Namibia, though..

- Advantages: In addition to making it easier to protect livestock from predators, having small camps close to the homestead, makes more intensive livestock management also possible. The increase in survival of young might compensate for any decrease in growth rates of the young livestock. Where irrigated pastures are possible, it can actually lead to an increase in production compared to more extensive free-range systems. This method can also be combined with various other methods.

- Disadvantages: Similar to kraaling, a built-up of parasites and disease epidemics are much more likely than with free-ranging livestock. Grazing close to the homestead and trampling of the veld, might lead to lower production than free-ranging options and make this method less sustainable.

- Limitations: The availability of enough good grazing around the homestead for all female and young (if calving/lambing seasons are used) or throughout the year (if young are born throughout the year), is an important limitation on this method. It is thus not a well-suited method for extensive farming in areas with low sustainable stocking rates.

AppendixA.1.26. Kraaling young livestock full-time
In contrast to kraaling of all livestock at night, this involves keeping the young animals in a predator-proof enclosure permanently, with the adult females joining their young to suckle only at night while grazing during the day. Or alternatively (especially in the hot summer-time), having the adults graze at night and suckling their young during the day. This has been a traditional livestock management technique in Northern Namibia (Francois Kok, Johann Britz 2013, personal communication; 105). A variation on this method would be to kraal all livestock full-time in a feeding lot. However, this has been found as not economically viable in Namibia [118], mostly because of high prices for livestock feed and long distances to market. .

- Advantages: For cattle this method has been shown to be quite effective in North Central Namibia. In some situations, with high livestock depredation levels, it might be one of the few solutions available. For natural "hiders", like goats (and cattle to some extent), where the young is not strong enough to keep up with the adults and would normally remain hidden in one place, while their mothers graze (in contrast to "followers", where the young are strong enough and remain with their mothers within the herd, like sheep; *cf* 48), this method combines well with intensive care of the young by the farmer. While the young in this method might initially grow slower than free-ranging young who are with their mothers all the time, they often make up for the difference by weaning age already.

- Disadvantages: This method is fairly labour-intensive (and thus costly). For each camp or cattle post with cows, a reliable worker is needed to let the adult cows out, while keeping the calves inside every day, 7 days a week. To be at all practical, it has to be combined with birthing seasons. If a single central kraal is used, the same issues with trampling of the veld and weaker growth and production starts to play a role. Some farmers also complain that this method result in weaker protective and mothering instincts in the cows when the calves are finally allowed to go out and graze with their mothers.

- Limitations: This is not a practical solution for extensive farming systems (e.g. where few water points, rough terrain and low grazing capacity result

in very large camps that a grazing cow cannot cross in single day) or where livestock do not have a single breeding season.

AppendixA.1.27. Changing breed or species of livestock
Where predation levels are very high, the best option for the farmer might be to change to other breeds or species of livestock. Cattle are in general less susceptible to depredation than small livestock. In mountainous areas, goats can experience less depredation than sheep (especially less surplus killing events). Behavioural attributes of different breeds can influence depredation in two ways [90]: 1) through behavioural traits making other management methods easier (e.g. making herding easier) or 2) through specific anti-predator behaviour (e.g. aggressive attacks of predators). Simple size might put livestock out of the preferred prey size range of some predators (e.g. cattle are not generally vulnerable to caracals). Damara and karakul sheep breeds are known to bunch together more in larger herds than breeds like dorpers. Sheep natural behaviour actually varies all the way from large grazing-while-moving herds, adapted better for lower grass cover, to more selective, more sedentary grazers, in smaller groups to sheep breeds that form territorial breeding pairs. Some breeds of European (Bos taurus) origin in South America developed anti-predator behaviour [67], while in North America the Brahman (Bos indicus) and longhorn cattle are known for their protective behaviour [159]. Cattle that know the kind of terrain on a farm (e.g. mountain-raised cattle) also tend to suffer less depredation losses than cattle from other areas. Generally, horned cattle breeds are likely to be able to better protect their calves than polled or short-horn breeds, but individual cows also differ in their protectiveness. Goats tend to scatter uphill when attacked by predators, leading to less surplus killing, unlike sheep that tend to mill around in one place (but sometimes defend their lambs better in the herd against smaller predators). Angora goats are also much more vulnerable to predation than Boer goats. There are unconfirmed claims by some farmers that by not weaning their female Damara lambs, it allows the mothers to teach their daughters how to protect their lambs and also help to establish a herd hierarchy, leading to less depredations losses to jackals. .

- Advantages: This method is simple and fairly easy to implement. However, in some cases it can have limited success in reducing livestock depredation unless combined with other methods. In very extensive farming systems, it might be the only option, combined with letting cattle horns grow [67].

- Disadvantages: The switch to other livestock species or breed can have negative economic consequences (e.g. beef is generally significantly cheaper than mutton and cattle has a much lower rate of increase than either sheep or goats). Because few farmers can afford to make such a switch quickly, any change has to be done slowly, leading to continued losses until the switch has been completed.

- Limitations: Dairy breeds are generally not well-adapted to the hot climate, thorny vegetation and long distances required to walk between grazing and drinking water typical of many parts of Namibia. Cattle are tall grass grazers, using their tongues to ingest grass, making a switch to cattle not an option in areas dominated by short grasses where tall grass grazers did not occur naturally. Additionally, for a stud farm where the stud might have built up over generations, switching to a different breed is both financially and emotionally not a realistic option (Harry Schneider-Waterberg 2013, personal communication).

AppendixA.1.28. Changing production livestock age
Some farmers in Namibia use a steer production farming system whereby they buy weaner calves and then graze the steers and heifers on natural grazing to gain weight in order to sell them at profit. By weaning age, most calves are no longer vulnerable to many predators and depredation losses can be minimal in this kind of farming system..

- Advantages: Especially when there are few predators larger then cheetahs on the farm, this method can be very effective. It is fairly easy to implement, although it needs careful record keeping and management to succeed economically. One major advantage is that with this method it is easier to quickly adapt stocking rates according to the rainfall (i.e. buy fewer new cattle when the veld condition is becoming bad).

- Disadvantages: No breeding selection is possible and the farmer is largely stuck with whatever is available for sale at the time of buying, with little control over livestock quality.

- Limitations: Steer production farming is impossible without enough weaner calves being produced (and offered for sale) in other cow-and-calf production systems. It is thus not an option for all farmers.

AppendixA.1.29. Horned cattle
Many livestock breeds that are native to or adapted well to Africa, have horns that help them in protecting their young from predators (e.g. Afrikaner and Nguni cattle). Putting experienced bulls, horned oxen and old cows with young animals in a single herds in order to teach younger animals how to protect against predators is a simple way to allow livestock to use their natural instincts and behaviour for reducing depredation losses..

- Advantages: This is one of the easiest methods when farming with horned livestock breeds, since it actually involves less labour and thus labour costs than the alternative of dehorning. It is also very easy to implement in extensive farming systems. When combined with strong behavioural breeding selection for those cows who are able to protect their young from predators, this can be a very cost-effective method to reduce livestock depredation, with higher wean percentages compensating for all of the

potential drawbacks. Together with choosing the right kind and breed of livestock, this might be one of the only methods available to very extensive farming systems [67].

- Disadvantages: Many farmers report that cattle with horns are more dangerous when handling them in the kraal or hurt each other when forced close together, e.g. in feeding lots or while being transported. Some feeding lots appear to discriminate against cattle with horns for this reason. Apparently some farmers also prefer dehorned cattle for aesthetic reasons (Johann Britz 2014, personal communication).

- Limitations: This method might not be good fit for those farmers whose primary market is feeding lots or who are farming with breeds that do not have horns for other reasons.

AppendixA.1.30. Grouping of livestock (holistic grazing with large herds)
While holistic grazing (short duration, high intensity grazing) was primarily developed for veld (grazing) improvement [18, 73, 144], it mimics another natural strategy used by many prey species to minimize depredation by crowding together for protection. Instead of having many small herds of livestock distributed through the landscape, having a single large herd (or only a few large herds) means both the chances of a predator encounter is smaller and that the herd is more able to protect its vulnerable members [90]..

- Advantages: Holistic grazing systems can result in improvement of the range-land, while often leading to lower production (because the livestock are forced not to graze selectively for high-quality plants), but because it mimics natural herd-forming behaviour of wild herbivores, it also leads to a significantly decrease in livestock depredation (Uwe Gressmann 2013, personal communication). This method can also be very easily combined with mixed herds for cattle to protect small livestock (see above on page 36).

- Disadvantages: Unless intensively managed adaptively, it can lead to veld degradation instead of improvement [28]. While negative trampling and piosphere effects have been demonstrated in arid and semi-arid regions of the world (e.g. 173), the suitability of holistic grazing compared to other grazing management systems like normal rotational grazing or adaptive grazing regimes (e.g. short period - at most 2 weeks - selective grazing early in the growing season, followed by long periods of grazing all grasses down after the grasses had seeded) has not been demonstrated where trampling will not result in a vegetative ground litter cover of the veld, simply due to too little vegetation available. In general, because livestock is forced not to graze selectively for more nutritious grasses, this method, while improving the veld in the long run, can cause lower production by livestock in the short term. General livestock management (e.g. vaccinations or early detection of any health issues) can be more difficult with large herds compared to smaller herds in separate camps.

- Limitations: This method might not be a good option for the more arid parts of Namibia and Southern Africa. Unless combined with other methods like herding dogs, herders or mobile electric fences, this method is not a good fit for livestock breeds in which the natural behaviour is to break up into small groups rather than flocking together in large herds. This method is less likely to work together with methods that disturb the natural territoriality of predators by removing individuals [90].

AppendixA.1.31. Sterilizing breeding alphas
This method is not primarily to keep predator numbers down as often supposed, but because for some predators (specifically canids like black-backed jackals and coyotes) where you have territorial alpha pairs who prevent others from breeding in their territories, they tend to depredate on livestock to feed their pups [148]. If there is no young, they can survive on other sources of food, similar to non-breeding individuals (cf 72). Denning (the killing of young and/or breeding alphas in their dens with poison fumes) or injection of predators with contraceptives works on the same principle..

- Advantages: Where the primary reason for livestock depredation is the feeding of their young, this method can be very effective.

- Disadvantages: This method is both difficult (finding the breeding animals in the first place) and expensive to implement (about US$ 600 per animal - 149).

- Limitations: Like lethal methods, this method is not really an option against threatened or scarce predator species. Only where most livestock depredation coincides with the breeding season of the predators on the farm, would this method have any chance of success. Because of the expertise and costs required this is not really an option for most farmers to implement by themselves.

AppendixA.2. Compensatory methods

These methods do not prevent livestock depredation, but in some way compensate or reward farmers or land-owners for having wildlife, including predators, on their land. One example of such a method that really worked well for wildlife in general (although not directly applicable to carnivores), was when Namibian legislation changed in 1967 so that all non-protected wildlife on a farm became the property of the land-owner. Before this, all wildlife belonged to the government and were generally considered as a nuisance by farmers who tried to rid their farms of these competitors with their livestock for grazing. This change caused wildlife to suddenly become a valuable resource for sustainable use of game animals for biltong and meat, resulting in an estimated 70% increase in game numbers and 44% increase in species diversity on farmlands [109]. Unlike the preventative and reactive methods, the success of these measures are not measured in number of prevented livestock kills and sustainability, but purely in

terms of the resulting sustainability of predator populations [121] and it is normally used as part of a conservation program for endangered predator species.
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Dickman et al. [40] give a good theoretical overview of various compensation schemes as fitting within the general "payments to encourage coexistence" (PEC) framework. They distinguish between 3 types of PEC: 1) compensation and insurance schemes; 2) revenue sharing; and 3) conservation payments. "An "ideal" PEC would: (i) minimize conflict by specifically targeting payments to those most directly affected by carnivores, (ii) reduce the direct costs of human–carnivore coexistence, (iii) provide local people with additional revenue directly linked to carnivores, (iv) avoid moral hazard and perverse incentives, (v) not require significant additional external revenue, (vi) specifically link payments to desired conservation outcomes, and (vii) be likely to have a positive impact on human poverty." Most of these aims have seldom, if ever been reached in actual compensation practices. Montag [116] makes the point that an important assumption of almost all compensation methods is that the conflict is an economic issue. In reality, most farmers have a sense of responsibility towards the livestock for which they care and monetary compensation does not address this. She also mentions the difference between typically utilitarian, rural view of wildlife and the typically recreational, urban view of wildlife. The political momentum and support for carnivore restoration and conservation largely comes from urbanized centres that neither live in the area of carnivores nor shares the livestock producing way of life. This illustrates why the conflict is often considered as primarily between different human groups, rather than between humans and predators (166, 116, 24, 95; discussed further below on page 7)..

AppendixA.2.1. Trophy hunting of predators
Because of the effectiveness of utilization of other game animals leading to an increase in their value and numbers on farms, many Namibian farmers are in favour of a similar use of predators via trophy hunting (Various, personal communication). A similar approach has worked for leopards in Uganda [166] and for lions in Africa [84, 21]. However, Treves [164] makes the point that hunting for protecting livestock and sustainable hunting for conservation of predators, are really different aims and might be ultimately incompatible. Too little is known about both predator behaviour and hunter behaviour to be sure that the aim of coexistence will be reached and therefore careful monitoring and adaptive management is required..

- Advantages: Putting an economic value on predators, can potentially change the attitude of many farmers to become more positive towards carnivores and if the value is high enough, to try and sustain carnivore numbers on their farms. Currently far more predators are killed in Namibia to protect livestock, than are trophy hunted; with many farmers taking a "shoot, shovel and shut up" attitude (102, 67; various Namibian farmers, personal communication).

- Disadvantages: Trophy hunting is normally selective for large males and can change the population structure of predators negatively if not managed properly [9, 77]. Additionally, it can cause other negative ecological effects like sexually selected infanticide (SSI) [12, 124]. Trophy hunting can ultimately have a negative impact on predator survival, unless it is very well managed [71]. Lindsey et al. [85] mention some current management practices that undermine the sustainability of lion trophy hunting and a number of changes to make it more sustainable - some of which might also be applicable to ensuring sustainable trophy hunting of other predators.

- Limitations: The greatest constraint on the use of trophy hunting of predators to help farmers become more positive about predators on their land, is that predators are on the top of the food chain. This means that a single predator can often use more than one farm as part of its home range and that a single farm with the available natural prey and habitat on it can often support only relatively few predators (compared to herbivores). Unless the income from a single trophy predator shot every few years surpasses the livestock losses due to those predators living on the land, it will not act as an incentive for farmers to sustain predator populations on their land. In this case trophy hunting of a predator will at best offset some of the costs spend by the farmer to prevent livestock losses (see also 109).

AppendixA.2.2. Compensation for livestock depredation losses

Compensation schemes have had mixed results [3]. The idea behind this method is to to make it possible for farmers to coexist with predators and to encourage it by paying them in part or fully for livestock losses due to predators. There can be three sources of funding for the payments, 1) government, 2) hunters' associations or 3) private conservation organizations [90]. Bauer et al. [13] mentions using tourism income to pay compensation for livestock losses due to lions (also 156). To function at all, such compensation schemes need to be 1) simple, 2) rapid and 3) safeguard against false claims [90]. Nyhus et al. [121] found the most effective compensation projects to be 1) fair, 2) transparent and 3) above all, fast. This included: 1) quick, accurate verification of damage; 2) prompt and fair payment. 3) sufficient and sustainable funds; 4) being site specific; 5) clear rules and guidelines (simple and transparent); 6) measures success appropriately as having an effect on numbers of predators killed. Dickman et al. [40] found that in practice compensation rarely covers all the costs of coexistence with predators. Paying below market value of losses are often done to prevent perverse incentive ("moral hazard") when the compensation pays better than taking livestock to market, resulting in farmers not expending any effort to prevent livestock losses and sometimes even claiming for non-predation livestock losses [121, 13]. Mishra et al. [114] opined that most initiatives to offset the costs of living with carnivores and to make conservation beneficial to affected people, have thus far been small, isolated, and heavily subsidized. Montag [116]concludes, "Compensation may be viewed as a useful tool, but one with

limitations and possible unanticipated adverse consequences.".

One of the few reported cases where such compensation appears sustainable and effective, involved a WWF funded project for Central Asian leopards in Turkmenistan [92]. However, it had a number of unique features: 1) The team included members of the local community, including the leader himself. It was thus not a case of "outsiders" running the project. 2) Local residents actively participated in planning a strategy for leopard conservation. 3) Instead of money or other means of compensation, it was decided to compensate farmers in kind (i.e. with other livestock to replace any livestock killed by a leopard). 4) Using the funding money from WWF a herd of sheep was bought, from which the offspring would be used to give compensation for depredation losses. 5) The herd became the property of the local-based Catena Ecoclub, enabling them to make decisions with regards to how the flock would be organized, how cases of leopard attacks would be analysed, etc. 6) Because the livestock herd can reproduce and was not used for any other purpose, this ensured the sustainability of the original WWF funding. A flock of 650-700 sheep would grow on its own and cover the cost of paying shepherds and veterinarians. 7) Next, 40 of the most influential and respected ranchers were invited to participate in a seminar where the project was explained to them. A council was elected to look after the herd on an annual basis and it was decided that the livestock would eventually become the property of the local farmers association once it was established. 8) This local council elected 2 experts to investigate cases of supposed leopard kills. 9) A simple procedure was established by which a farmer would register a case of livestock losses, and the experts would not only decide whether it was truly a leopard kill, but also whether the farmer's livestock were properly managed to prevent predation. 10) The local communities were kept up to date about the progress of the project using poster display stands and education. The long-term plan was to combine education and compensation to ensure the survival of Central Asian leopards. Perhaps the most important lesson from this case study was the role of local leadership in all phases of the project, ensuring that the long-term beneficiaries and implementers of the project were also involved in the decision-making process and the resulting project was well-adapted to local conditions (see also 3). The separation of the two arms respectively verifying predation kills and the other deciding on how much compensation needs to be paid, appears to be a general requirement for successful compensation schemes [121]..

- Advantages: Most farmers agree that compensation is a nice idea if implemented properly [139]. In areas without any natural prey and where predators are dependent on livestock for their survival, this might be the only way to achieve coexistence of livestock and predators [90, 114].
- Disadvantages: One obvious drawback to this method is that on its own it gives no incentive for farmers to protect their livestock from predators. Additionally, it is not always easy for farmers to prove that losses were due to predators, especially when the whole prey animal is consumed. Failed

expectations of farmers about compensation often result in unanticipated negative results, when farmers become even more negative towards predators than before [116]. Mishra et al. [114] mentioned that some reasons why current compensation schemes did not work, including 1) time and costs involved in getting compensation and 2) low compensation rates (only 3% of total loss). The greatest issue with this method is the question of who should be responsible for funding the compensation and how to keep funding sustainable. The difference between urban and rural values [116, 139], where sometimes farmers have the perception that people who do not have to deal with the consequences, are trying to manipulate them into keeping predators on their land, can also result in the situation where compensation payouts have no significant effect on tolerance for predators [120].

- Limitations: This is not really a method that an individual farmer can implement, but it needs the cooperation of various role-players, with policy, responsibilities and roles well defined to address issues about the legality and liability of wild-life damage, Endangered Species Act legislation, and private property rights. In situations with protected species, the government is the only body that can assume certain responsibilities for human-wildlife conflicts in areas where wildlife is under the stewardship of the people [116].

AppendixA.2.3. Insurance schemes for livestock depredation losses
Few instances of successful insurances schemes for livestock depredation losses have been reported (114 discuss one notable exception). This method basically shares the same strengths and weaknesses of direct compensation for livestock losses. However, it differs in that the farmers themselves carry the costs for the compensation. Insurance is commonly used in Europe, but in general an unsubsidised, purely private insurance scheme is not viable [122]..

- Advantages: Especially given the high reported rates of livestock losses and its uneven distribution (e.g. 171), insurance might be an affordable and sustainable way to compensate for livestock losses. It can make the compensation independent and provide something that farmers can mostly do for themselves, instead of having to rely on outside funding organizations or government like other compensation schemes. This method can provide farmers with some peace of mind and works well with almost any other method. Where insurance is working well (i.e. sustainable), payment of rewards for those farmers with the least number of livestock losses to predators (least number of claims), can be an added incentive for good livestock husbandry practices, combining insurance with preventative methods (e.g. 114).

- Disadvantages: Paying for insurance against depredation losses still equate to a nett loss for most farmers [116]. Most insurance companies do not have the expertise for a realistic assessment of livestock depredation risks

and setting realistic premiums, therefore it is usually very expensive and only worthwhile in cases of extremely high livestock depredation rates. And like with direct compensation, there is the need for verification of predator kills when livestock are lost [148].

- Limitations: Insurance against depredation livestock losses is not offered by most insurance companies in Southern Africa, so unless the agricultural unions can set up their own insurance scheme, it is unlikely to be available. However, it appears likely that it would not be economically viable according to Nyhus et al. [122].

AppendixA.2.4. Compensation for predators on farmlands
This is one of the few compensation methods where successes have been recorded (e.g. 114). Instead of directly paying farmers, paying price premiums for their produce (e.g. the "Wildlife Friendly Meat" project by Conservation South Africa in Namaqualand, South Africa) is an alternative method to compensate formers for coexisting with predators on their land. Instead of paying for losses of livestock to predators, the meat from farms who followed certain management practices were to be branded as "Wildlife Friendly", sold in Woolworths stores for higher than normal prices with the price premium being passed on to the farmers. Such niche marketing basically depends on changing the level of predation loss that is economically (and socially) acceptable to farmers [148]. It helps to shift the cost of having predators on their land to the consumers who prefer "green" non-lethal methods of predation control..

- Advantages: Unstable markets and fluctuations in the prices of livestock products is a major issue for all commercial farmers. A price premium is one important way to help farmers manage the risk of coexisting with predators on there land instead of aiming for extirpation of all predators. Trough rewarding livestock farmers directly for conserving predators on their land, the real aim of these kind of compensation schemes is directly addressed (instead of a roundabout way of partial compensation for economic losses only). The farmers protecting their livestock well using preventative methods, still score by having greater livestock survival rates; i.e. there is no danger for perverse incentive to allow livestock depredation in order to be compensated (*cf* the snow leopard case study mentioned by Mishra et al.).

- Disadvantages: Unless such a compensation scheme is adapted well to the local situation (e.g. by including local agricultural leaders in the planning and decision-making process), lack of participation by farmers might make it useless. Because many of the threatened predators have home ranges that overlap with more than one farm, a single farmer or even a few dispersed farmers, might not contribute much to the long-term survival of predator species. Finding shops that are willing to sell predator-friendly livestock products as a separate brand and are moreover willing to pass the premium price on to the farmers, is difficult. Similar efforts in Namibia to

market and sell "cheetah-friendly meat" in the past fell apart because 1) it was difficult to ensure farmers' compliance with the required management practices and 2) separate branding and marketing (and passing higher prices on to the producers) was an issue for the supply chain (L.L. Marker 2013, personal communication). There was and still is uncertainty on whether the demand for such products is high enough to sustain a higher price. Consumers might support the idea of "predator-friendly" meat production, but are they actually willing to pay more for such meat? Woolworths, as a franchise that targets the upmarket section of consumers, might be considered as the ideal partner in such a project, but up to the present higher producer prices have still failed to realize in practice. Like in the case of compensation for livestock losses, the numbers of predators on a farm now have to be confirmed before payment is possible [122]. Direct payment for predators suffers from the same issues with sustainable funding as compensation for livestock depredation.

- Limitations: This is not really an option for a single farmer without the support of at least the local farmers association or even better, the national agricultural union.

AppendixA.2.5. Ecotourism
Like trophy hunting, ecotourism is another way to benefit directly from predators on farmlands. In communal areas, where regular income from livestock sales are relatively low [60, 61], ecotourism involving predators can potentially generate greater income than livestock farming [157]. .

- Advantages: Ecotourism can increase farm income a lot and in some cases even replace livestock farming [109]. The possibility to see predators in the wild is a significant drawing card for many tourists and hunters [67]. Unlike many of the other compensation methods, it can be implemented by a single farmer on his own land.

- Disadvantages: Because predators are often so elusive, tourists might be disappointed and avoid returning to a tourist enterprise if they had unrealistic expectations of seeing a predator in the wild. It is difficult to combine tourism with hunting. Most livestock farmers do not have the skills or inclination for the kind of work required for a well-managed tourism enterprise [109]. Becoming known well enough to attract enough tourists to compensate for all livestock losses due to predators, will probably also take some time. Some "ecotourism" activities, like using baits to attract predators for tourists, can habituate predators to humans and teach them to associate humans with food, leading to more livestock depredation and even endangering people's lives [67, 4]!

- Limitations: Finding wild predators for tourist viewing require excellent tracking skills, a soil substrate in which tracking is relatively easy, and enough time, unless some of the predators have been radio/GPS collared.

Tourism is not a realistic option for remote farms in a monotonous landscape that are unlikely to attract many, if any, tourists.

AppendixA.3. Reactive methods

Reactive methods have the advantage that unless there are real losses to predators, nothing or little needs to be done. As long as there is little livestock depredation, the implementation costs are also low. Of course, it can always be combined with other methods. The greatest disadvantage of these methods is that they usually do not prevent any livestock losses and the farmer might experience significant losses before implementing a reactive method. For this reason, these methods are generally better for situations where livestock losses are infrequent and not useful at all for areas where depredation of livestock is common. The main aim of reactive methods is thus to prevent further losses, after a predator already attacked livestock..

AppendixA.3.1. Hunting and trapping reactively (killing a single "problem predator")

In contrast to the preventative use of hunting to eradicate predators or decrease predator numbers, hunting (with or without dogs) can also be used reactively. In this case the main aim is to kill the specific individual that was responsible for killing the livestock. Even if the method does not result in any actual decrease in livestock depredation, it does give the farmer some intrinsic satisfaction to kill the guilty predator[53]. However, Chapron and Treves [30] showed that allowing killing of predators or government culling of predators did not make livestock owners more positive towards predators, but actually increased illegal killing of predators. An important assumption, and one that has been challenged (e.g. 89) is that there are specific individuals that become livestock killers or "problem animals". For some species (e.g. coyotes - 143, 72) it is fairly clear that a few individual animals are responsible for most of the livestock depredation [155], while the majority of the predators prefer natural prey, but for other species it appears as if predators simply utilize livestock within the right size range according to their availability, making little differentiation between livestock and other prey species. In the latter case, removing any individual animal will simply result in its place been taken be another individual who will continue to prey on livestock, at most giving a short reprieve in livestock losses, while having a destabilising effect on the ecosystem (and its sustainability). It has long been known that removal of a single predator can sometimes temporarily stop any further livestock losses. Jaeger [72] showed that in coyotes (which have similar behaviour to black-backed jackals, see also 48, 49) it is principally the resident alpha breeding pair that are killing livestock and removing them will stop livestock killing until a new alpha pair is established three to four months later. Indiscriminate killing of coyotes had no effect on livestock losses at all, mostly because the betas and transient individuals were much more vulnerable to capture than the alphas. However, they did not investigate what the effect will be a year later, and the Conradie and Piesse [32] study showed that it could increase

livestock losses in the next year. Two possible ecological explanations for such an increase could be that the neighbouring alpha pairs expand their territories so that the territory which used to have one territorial breeding pair is now shared by 6 or more breeding pairs. Alternatively, the betas might start breeding in the next year since there is no alpha pair to suppress their breeding. Balme et al. [12] suggested the following procedure to ensure that only habitual livestock killing leopards were removed: 1) inspect depredation events within 24 h of being reported; 2) if a leopard is verified as being responsible for the damage, an attempt is made to identify the individual by deploying camera-traps at the kill site; 3) a destruction permit is granted only when the same leopard is known to be responsible for at least three depredation events within a 2-month period. A similar method has been used occasionally in Namibia, but using a GPS collar on the suspect leopards, instead of camera traps (Stuart Munro 2015, personal communication)..

- Advantages: Since it is only used after livestock had been killed, it can be substantially less expensive than pre-emptive hunting. Especially if dogs are used to take the trail from where livestock have been killed, this method can be very selective in order to kill the specific individual that was responsible for killing livestock.

- Disadvantages: If the guilty predator was not a habitual livestock killer, removing it might have no effect at all on the livestock losses. In the case study from the Ceres Karoo hunting club [32], predators were mostly killed in response to livestock losses. And yet, the result was that those farms where most predators were killed in a certain year, had an increase in livestock depredation in the following year (however, there is little indication that this killing was very selective). This method might therefore not be very effective. It is actually quite difficult to be certain that the specific individual who had killed livestock, is being targeted. Moreover, there has been recorded instances where an individual collared male leopard that killed many livestock in a single night, on two neighbouring farms, afterwards walked past within 50 m of the same livestock kraal, without ever killing a single livestock animal again over a period of 6 years (Quinton Martins 2010, personal communication). Removing the predator might thus have no effect on future livestock losses at all.

- Limitations: Being selective and finding the guilty predator is very dependent on any livestock depredation events being found shortly after the kill. If the livestock are spread wide over a big farm or the labour force on the farm is small, this might not be practical. It might really only be effective in those situations where an individual predator has become a specialist killer of livestock. As shown by Linnell et al. [89], a single "overkill" (surplus killing) event does not mean that the individual predator has become a habitual livestock killer.

AppendixA.3.2. Translocation of problem animals
In effect this has pretty much the same effect as trying to kill a problem individual. However, for threatened or scarce species, relocating an individual that has killed livestock to somewhere else, might save the life of that specific animal and could have a positive effect on the survival of the species overall. This is also a reactive method in that individuals that has killed livestock, are targeted..

- Advantages: For scarce or threatened species where each individual is important, moving a "problem animal" to somewhere else, can mitigate conflict, decreasing livestock losses, and advance the survival of the predator species [176]. Similar to killing reactively, it is aimed at removing a single "problem animal" (or pride of predators) that has been killing livestock habitually.

- Disadvantages: This method will make no difference if there is no single "problem" individual. Linnell et al. [89] makes the point that there are two kinds of "problem predators": those who are simply in the wrong place (i.e. hunting in a habitat where there are lots of livestock) or those who actually start to specialize in killing livestock. In the former case, the territorial animal who was responsible for livestock losses will simply be replaced by one or more others who will continue killing livestock. Various studies have shown that predators, especially felids, often move great distances after having been relocated, and either resume killing livestock somewhere else or return to their original home range (and sometimes continue killing livestock there) [157, 174, 175]. Additionally, if it is moved into an area with high densities of conspecifics, a territorial predator will either have to replace the current inhabitants of the territory (followed by SSI in males), be killed by a current territorial individual, or have to move out and find an empty space for itself, often on farmlands again. Relocating some species over long distances can compromise their genetic integrity [138], thus diluting their adaptability to local conditions. Compared to just shooting the problem animal, it is quite an expensive method, with an estimate for leopard relocation in Namibia of USD $3 140.00 per animal [176]. However, it is one of the few available methods where the farmer does not have to carry all the costs (except for the initial capture of the predator), which might partially explain its popularity in Namibia.

- Limitations: For stock-killing lions, Stander [155] found that relocation of habitual livestock killers did not work, with the lions simply moving back to areas where they would continue to prey on livestock. In this case, relocation of lions was only successful for occasional livestock killers. The second constraint was that lion prides had to be either relocated to their original territories within protected areas, or moved to areas where there were no other lions yet. The same principles might be true for some other predator species. However, this necessitates that enough is known about both the animals that are to be relocated and the area to which they will be relocated. Weise et al. [176] found that there are some

situations in which leopards can be successfully translocated in Namibia. However, the model will differ between countries and species. For leopards in Namibia, it was hypothesized that translocation should happen over distances larger than 200km, to a conservation area (or land-use without conflict potential) of at least 875 km^2, with current low resident leopard densities (<2 leopards/100 km^2) and with releases at least 18 months apart to mimic natural dispersion events of sub-adult leopards. Although having a data point of one female only, a soft release method appeared to result in less movement post-release. The model had a 67% to 83% success rate (depending on how success was defined), but they still did not recommend it as a standard response to carnivore conflict, since there are only a limited number of places in Namibia left to which leopards (or other predators) can be relocated using the attributes required by the model of Weise et al. [176].

AppendixA.3.3. Poisonous Livestock Protection Collars (LPC)
One of the few uses of poison that can be defended from an ecological point of view, is the use of collars on livestock with poison pockets around the throat of the sheep [90, 20]. .

- Advantages: This is the only use of poison that are selective in killing only those predators that attacked livestock. This could lead to surviving predators avoiding sheep in future. However, since the poison is usually very effective, there are very few if any survivors. The farmer do have the personal satisfaction of the guilty predator being killed.

- Disadvantages: The greatest disadvantage is that the attacked sheep is still killed in order to kill the predator! Moreover, if any predators survive biting into the collar, they might learn to avoid the collared sheep only, while still attacking other sheep. The other great disadvantage of poison collars are high costs of the collars. This means that not all sheep can be collared, and thus that sheep without LPC's remain vulnerable to predators. Additionally, it has all the disadvantages of other kinds of collars (labour, collars needing to be replaced regularly in growing sheep, predators changing their attack method to avoid the neck or throat, etc.).

- Limitations: Depending on the poison used, sometimes scavengers that eat from the carcass of the predator killed by the poison might in turn die from the poison... an ecological ripple effect killing non-target animals and loosing all the advantages of the collars being more selective than other uses of poison. Because the poison is also dangerous to humans and house animals, care is needed when using the collars.

You can use either BibTEX:

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