Scientific Assessment on Livestock Predation in South Africa

CHAPTER 9

BIOLOGY, ECOLOGY AND INTERACTION OF OTHER PREDATORS WITH LIVESTOCK

Michael J. Somers[1,2], Harriet Davies-Mostert[1,3], Nkabeng Maruping-Mzileni[4], Lourens Swanepoel[5], Emmanuel Do Linh San[6], Andre Botha[3], Julius Tjelele[7], Lihle Dumalisile[8], Kelly Marneweck[3], Marion Tafani[9] & Axel Hunnicutt[1,11]

Contributing authors: Craig Tambling[6], Liaan Minnie[10]

[1] Centre for Wildlife Management, University of Pretoria, Pretoria
[2] Centre for Invasion Biology, Mammal Research Institute, University of Pretoria, Pretoria
[3] Endangered Wildlife Trust, Johannesburg
[4] Conservation Science, Somerset West
[5] University of Venda, Thohoyandou
[6] Department of Zoology and Entomology, University of Fort Hare, Alice
[7] Agricultural Research Council, Pretoria
[8] Gauteng Department of Agriculture and Rural Development, Johannesburg
[9] ICWild, Department of Biological Sciences, University of Cape Town, Cape Town
[10] University of Mpumalanga, Mbombela
[11] Wild Tomorrow Fund, New York

INTRODUCTION

While it is well known that large carnivores are important in the top-down regulation of food webs, small carnivores can also, especially in the absence of the large carnivores, play a pivotal role in ecological processes (See Do Linh San & Somers, 2013; PredSA Chapter 7). Predators can affect the density and dynamics of prey species, with cascading effects on whole ecosystems (Beschta & Ripple, 2006; Ripple & Beschta, 2007; Wallach *et al.*, 2010). Large predators, for example, African wild dogs (*Lycaon pictus*), are also important tourist attractions (Lindsey *et al.*, 2005a). The removal of large predators from an ecosystem may have many unexpected consequences which, from an ecosystem services perspective, can often be regarded as negative. In South Africa, many top-order predators have been historically extirpated from much of the land, with some species (e.g. lions *Panthera leo*) surviving only in formally protected areas. Some other species such as cheetahs (*Acinonyx jubatus*), spotted hyenas (*Crocuta crocuta*), and African wild dogs, although still occurring outside protected areas, are probably dependent on them for continued survival (Mills & Hofer, 1998).

An estimated 68.6% (839 281 km^2) of South African land is used for domestic livestock farming and game ranching (Thorn *et al*., 2013). The resulting habitat fragmentation caused by this extensive farming disturbs the movement of animals with large home ranges, including many predators and their prey (Woodroffe & Ginsberg, 1998), which brings them into conflict with people and their livestock (Thirgood *et al.*, 2005). Also, the increasing human density along South Africa's reserve borders is escalating the conflict. There have been numerous reintroduction attempts (some successful, some not) around the world, including South Africa (Hayward & Somers, 2009) and many of these have taken place in small protected areas with substantial edge effects and a high chance of escape (Hayward & Somers, 2009). In those areas where there has been a historical eradication of predators, there is little culture of shepherding livestock. Conflict is therefore unlikely to decrease and needs to be identified and mitigated against (see PredSA Chapter 6).

Many predators in South Africa exist outside protected areas, and modifications to their habitat by agriculture and other human activities can increase the frequency and intensity of carnivore conflict situations (Thorn *et al*., 2012). Humans are now the main cause of predator mortality (Lindsey *et al.*, 2005b; Hemson *et al.*, 2009). This is often because the health and livelihoods of humans living near carnivores are often compromised by the predators (Gusset *et al*., 2009; Dickman, 2010). Livestock production in Africa varies from large scale operations to small scale subsistence livestock farming, typical of most of rural Africa, and many of these people face formidable economic pressure (Hemson, 2003).

In natural predator-prey systems, ecological separation occurs on the axes of space, time and diet, which provides a mechanism for species coexistence (Schoener, 1974). With the presence of livestock, this dynamic may change. Predators may alter their activity and movement patterns based on the presence of an abundant, easy to catch prey (e.g. Somers & Nel, 2004). Much of the discussion below needs to be seen in the light that predation is context dependent.

In South Africa, two of the smaller carnivores – caracals (*Caracal caracal*) and black-backed jackals (*Canis mesomelas*) – are responsible for most predation on small livestock (van Niekerk, 2010; Badenhorst, 2014; PredSA Chapter 8). However, other species are implicated in livestock predation in this country, including lions, leopards (*Panthera pardus*), cheetahs, servals (*Leptailurus serval*), African wild dogs, side-striped jackals (*Canis *adustus*), Cape foxes (*Vulpes chama*), free-roaming dogs (feral or human-fed) (*Canis lupus familiaris*), spotted hyenas, brown hyenas (*Parahyaena brunnea),* honey badgers (*Mellivora capensis*)*,* bushpigs (*Potamochoerus larvatus*), chacma baboons (*Papio ursinus*), crocodiles (*Crocodylus niloticus*), and various corvids and raptors (e.g. Badenhorst, 2014).

Here we briefly assess aspects of the biology and ecology of predators and how this affects livestock predation. We then review the evidence of their involvement in predation, and we identify which livestock are attacked, categorise the evidence of them attacking livestock, and broadly categorise the severity of this predation. The ecology and behaviour of the main livestock predators are reviewed to determine how these affect the interaction with livestock. We also identify any potential gaps in the knowledge base which require future research.

DETERMINING FACTORS FOR LIVESTOCK PREDATION

Carnivore-livestock conflict has driven human-carnivore conflict since the domestication of animals and needs to be addressed to secure the livelihood of farmers and conservation of predators (Minnie *et al.*, 2015). Unfortunately, there are few data on the spatial distribution of livestock predation and the associated management responses by farmers (Minnie *et al.*, 2015). Ultimately, the primary cause of conflict is habitat loss. For example, an estimated 75% of lion’s range in Africa has been reduced and what remains is increasingly fragmented (Riggio *et al.*, 2012).

Many ecological and biological variables can affect the likelihood of livestock predation. Factors such as the distance of the farm from water sources, distance from protected areas, elevation and surrounding vegetative cover may all play a role (Knowlton *et al.*, 1999; Kolowski & Holekamp, 2006; Mattisson *et al.*, 2011; Dickman, 2010; Thorn *et al.*, 2013; Minnie *et al.*, 2015). Thorn *et al.* (2013) concluded from their work in North West province that the distance to protected areas is the most influential variable that determines the risk of predation. This could suggest that predator communities are often restricted to protected areas and that they incorporate the surrounding farming matrix in their home range, causing the conflict (Distefano, 2005).

Owing to the nature of many predators and the influence of prey size, cattle are less likely to be targeted as prey by predators such as cheetahs and leopards (Sinclair *et al.*, 2003). Data on predation events depend on the farmers and their ability to keep accurate records of species affected and numbers lost, and their willingness to share the information. Some farmers are not always willing to report on predation, especially if they practice illegal predator control methods (L. Dumalisile pers. obs. 2017).

Diet and prey selection of predators in South Africa

Diet and prey selection of vertebrate predators are primarily driven by mass-related energy requirements (Carbone *et al.*, 1999). The threshold for obligate vertebrate carnivory is around 21.5 kg (Carbone *et al.*, 1999), which suggests that predators such as lions, leopards, spotted hyenas, cheetahs, Nile crocodiles and to a lesser extent free-roaming dogs are suggested to predate on prey exceeding 45% of their body mass. It is therefore predicted that these predators are more likely to be livestock predators than smaller vertebrate predators (e.g. servals, side-striped jackals, Cape foxes, honey badgers, otters). While mass-related energy requirements provide a framework to quantify the inclusion of prey weight categories into predator diet, other factors related to predator behaviour (e.g. ambush versus cruising predators), prey behaviour (e.g. vigilance behaviour), predator morphology, and habitat requirements related to hunting or escape can all affect prey selection (Kruuk, 1986). Furthermore, factors like prey catchability, which is related to habitat characteristics (Balme *et al.*, 2007) and prey vulnerability (Quinn & Cresswell, 2004) are emerging as key factors affecting prey selection (and hence diet) of predators. Therefore, the inclusion of livestock in predator diets will be affected by predator distribution, predator density, predator size, predator hunting behaviour, prey behaviour, prey vulnerability, prey catchability, and density of natural prey. When the diet of predators is determined by scat analysis prey which has been scavenged and not preyed on could be included. Scat analysis should therefore always be kept in context of other evidence such as direct observations.

While there is a rich body of research investigating the prey preference and selection in South African carnivores (e.g. Hayward & Kerley, 2005; Hayward, 2006; Hayward *et al.*, 2006a), little (e.g. Forbes, 2011; Humphries *et al.*, 2016) is known about carnivore diets in non-protected areas where predation of livestock would most likely occur. Several questionnaire-based studies have investigated the predation of livestock by carnivores (van Niekerk, 2010; Chase-Grey, 2011; Thorn *et al.*, 2013; Badenhorst, 2014). The consensus among interview-based studies suggests that carnivores often predate on livestock which inadvertently leads to retaliatory killing (Thorn *et al.*, 2012; Thorn *et al.*, 2013). In contrast, several studies have, using scat analysis, quantified carnivore predation in non-protected areas (livestock and game farms), where results often contradict questionnaire-based research (Chase Grey *et al.*, 2017). For example in the Waterberg Biosphere (South Africa) and Vhembe Biosphere (Soutpansberg, South Africa) landowner interviews reported high livestock predation by predators (Swanepoel, 2008; Chase-Grey, 2011), while scat analysis and GPS located kills found no livestock in leopard diet (Swanepoel, 2008; Chase-Grey, 2011; Chase Grey *et al.*, 2017). There, therefore, appears to be a mismatch between questionnaire-based research and carnivore diet quantified based on scat analysis and GPS located kills. Predators select wild species over domestic stock, but if natural prey are scarce, predators will increase livestock in their diet (Schiess-Meier *et al.*, 2007). The prevalence of livestock in a selection of predators for which data are available is reported in the species accounts below, while information on the remaining predators is provided in Table 9.1.

Activity patterns of predators and how this affects livestock predation

Predator activity patterns vary with species and have evolved through a diverse range of selection forces. Activity patterns of predators are potentially influenced by a number of aspects such as direct or indirect competition with other predators (e.g. Saleni *et al.*, 2007; Hayward & Slotow, 2009; Edwards *et al.*, 2015; Swanson *et al.*, 2016; Dröge *et al.*, 2017), or the activity patterns of their prey (e.g. Hayward & Slotow, 2009). Not all predators are nocturnal or active at the same time. Some such as African wild dogs, chacma baboons, crocodiles, and raptors are diurnal, and therefore pose a risk during the day. Wild ungulates' perceived risk of predation can affect resource use and activity budgets (Brown *et al.*, 1999). Livestock, however, although able to perceive the risk of predation, cannot do much to reduce it. They are managed and can only avoid predation if managed appropriately (see PredSA Chapter 6). To avoid or reduce predation on livestock it is, therefore, crucial to understanding the activity budgets of local predators. Putting livestock indoors, or in protected kraals at night may protect them against nocturnal predators, while having herdsmen or guard animals may help during the day (see PredSA Chapter 6). Although most animal species have a "baseline" activity pattern, a deviation in behaviour from the baseline occurs due to the interaction with their environment (Snowdon, 2015). Large carnivores have different abilities to adapt. Those with high behavioural plasticity and flexible ecological traits are those that recover easily from depletion and which are more inclined to live close to humans (Cardillo *et al.*, 2004). For example, spotted hyenas change their demographic structure, social behaviour, daily activity rhythm, and space use in response to increased livestock grazing (Boydston *et al.*, 2003). Table 9.2 summarises the broad activity patterns of the relevant predators with Fig 9.1 giving broad activity patterns of the large carnivore guild.

Social structure of predators and its influence on livestock predation

The influence of home range size and territoriality on predation

Predators often have large home ranges which often draw them into conflict with people (Treves & Karanth, 2003; Graham *et al.*, 2005). An animal's home range is defined as "the area about its established home which is traversed by the animal in its normal activities of food gathering, mating and caring for young" (Burt, 1943). For predators, home range size is influenced by several factors, including the spatial distribution of available prey (Hayward *et al.*, 2009), metabolic needs, and diet (Gittleman & Harvey, 1982). For example, obligate vertebrate carnivores (in other words, those most likely to come into conflict with livestock farmers) tend to have the largest home ranges (Gittleman & Harvey, 1982), which complicates their management.

The spatial ecology of predators is based on their need to fulfil physiological, ecological and social requirements (Owen-Smith & Mills, 2008a). These requirements are met with a combination of habitat suitability (Ogutu & Dublin, 2002), resource availability (Owen-Smith & Mills, 2008a) and social dynamics (Packer *et al.*, 2005; Loveridge *et al.*, 2009). Home ranges are thus sufficiently large to ensure access to key resources such as food, water, shelter and access to breeding mates (De Boer *et al.*, 2010). Animals usually adjust their location in space until their requirements have been met, thus defining a home range (Abade *et al.*, 2014). Consequently, environmental disruptions can alter home range selection and subsequently, negatively impact upon the various requirements of an individual or even a population (Packer *et al.*, 2005). Similarly, social disruptions (e.g. caused by the excess removal of males) can alter the social organisation of predator species which can potentially increase the roaming behaviour or resident animals, or lead to an influx of new animals (Balme *et al.,* 2009). Both these scenarios can inadvertently cause greater movement of predators, both from within protected area to the outside, or from outside in, which can potentially increase conflicts with livestock.

Home range sizes vary between animals of the same species, and this variation can be considerable, demonstrating their ability to adjust resource use in response to local conditions (Moorcroft & Lewis, 2013). A predator's movements within its home range are influenced by the availability of prey: for example, when prey are scarce, African wild dog packs traverse their entire home range every 2-3 days, whereas during periods of greater prey availability ranges are much more restricted (Frame *et al*., 1979). Similarly, home ranges of lion prides in the Kalahari – a prey-scarce ecosystem – are 6-10 times larger than in Kenya, where prey are substantially more abundant (Schaller, 1972).

These variations have an important bearing on predator-livestock conflict, especially where human activities, such as habitat alteration, or the exclusion or exploitation of natural herbivores, have led to reductions in the prey resource base for predators resulting in the likelihood of attacks on livestock (Graham *et al.*, 2005).

Seasonal variation in the spatial organisation may also influence the degree and spatial scale of predation. For example, for about 3 months each year during the denning season (which, in South Africa, takes place in the southern hemisphere mid-winter), African wild dogs occupy only a portion of their annual home range (average 50–260 km^2 vs 150–2,460 km^2; Hunter & Barrett, 2011). During this time it can be assumed that local impacts on prey can be more pronounced. However, a study of this phenomenon in the lowveld of Zimbabwe suggests that these concerns are unfounded in some situations (Mbizah *et al*., 2014).

In a global review of human-predator conflicts, Graham *et al*. (2005) found that a third of the variance in the percentage of livestock (and game) prey taken by predators was explained by a combination of net primary productivity and predator home range, where percentage of prey was inversely related to both productivity and home range. The influence of home range on predator density is the likely mechanism affecting this pattern (Graham *et al.*, 2005), where larger home ranges tend to belong to larger species occurring at lower densities.

Carnivore home ranges also vary greatly in their level of exclusivity, from loosely defended home ranges to heavily defended, mutually exclusive territories. A territory may be defined as “a fixed space from which an individual, or group of mutually tolerant individuals, actively excludes competitors for a specific resource or resources” (Maher & Lott, 1995). These variations have important consequences for demography, and consequently for ecological relationships, including predator-prey dynamics and management strategies to influence these. For example, territorial animals such as femalemustelids tend to have mutually exclusive ranges, limiting the overall population density and mobility across a landscape. Disruptions in population spatial structure (for example, lethal or non-lethal removal of resident individuals) may have unpredictable effects on home range placement. Highly territorial species are excellent candidates for non-lethal methods of conflict management that allow for the presence of resident predators that do not kill livestock themselves but keep losses low by excluding other predators from the area (Shivik *et al.*, 2003). Small home ranges may indicate high predator density and therefore high predation frequency; large home ranges may lead to regular contact with prey "patches" (Graham *et al*., 2005), thus exacerbating conflict.

Social organisation and its influence on predation

Predator social organisation has an important bearing on livestock depredation risk and, in turn, the mechanisms by which conflict can be effectively mitigated. Predators can be broadly classified as group-living or solitary, where group-living species are those in which individuals regularly associate together and share a common home range, and solitary species forage alone (Gittleman & Harvey, 1982). A comparison between solitary leopards and social African wild dogs neatly exemplifies this point: leopards are spaced out individually, and predation incidents typically involve just one individual within a population – and not all individuals. So you may have a problem in one place and not another depending on an individual. In contrast, African wild dog packs hunt together, and therefore the entire pack would be responsible for predation. They, however, have large home ranges, so effects on predation are not localised.

Related to this is that group-living predators tend to be more visible when they come into contact with humans and their livestock and therefore are less tolerated. Conversely, solitary predators tend to be more cryptic. Consequently, human perceptions of the predation impact of group living predators may be exaggerated.

Density of predators and how it affects livestock predation

Management, land use practices, previous land use, and activity in neighbouring properties/farms influence habitat quality and can play a significant role in determining the local density of predators (Balme *et al.*, 2009; Rosenblatt *et al.*, 2016). Alterations in landscape features and land use are key drivers of habitat degradation and fragmentation leading to declines in predator populations. This is particularly true for South Africa, where there has been a significant shift from livestock farming to game farming (Carruthers, 2008; Taylor *et al.*, 2016). Furthermore, as the viable habitat and resources available for predators decline with increasing human populations, the need for predator conservation and wildlife management efforts increases (Friedmann & Daly, 2004). For example, lions require large expanses of land with adequate food, water and shelter resources (Schaller, 1972). For lions to survive and thrive, the land use must be restricted and dedicated to wildlife (see Ferreira

& Hofmeyr 2014). This can be in the form of game farming or protected areas. Although lions can cross through ill-maintained fences, if the habitat quality and food resources within the game farm or protected area are adequate, the likelihood of transgression into neighbouring areas is low.

There appear to be several mechanisms, not necessarily mutually exclusive, that drive the patterns in predator densities. First, the conflict between landowners and carnivores is often reported in areas where land use is dedicated to consumptive wildlife utilisation or livestock production (Dickman *et al.*, 2015). Such conflict often results in persecution which directly reduces carnivore densities, even when prey densities remains adequate to sustain high carnivore populations (Balme *et al.*, 2010). For example, leopard densities in prey-rich game farming areas can be as low as 20% of potential densities (Balme *et al.*, 2010; Swanepoel *et al.*, 2015). In contrast, studies have highlighted that non-protected land can have equal or even higher carnivore densities than protected areas (Stein *et al.*, 2011; Chase Grey *et al.*, 2013; Swanepoel *et al.*, 2015). Such higher densities can be attributed to high prey biomass and or reduced intraspecific competition. For example subordinate predators such as cheetahs maybe in higher densities in non-protected areas as there are fewer dominant predators such as lions. However, such high carnivore densities can also be due to temporary immigration into these areas due to high removal rates (Williams *et al.*, 2017). Secondly, prey populations in non-protected areas can be depleted due to poaching, habitat modification and game-livestock competition which could limit the density of carnivores (Rosenblatt *et al.*, 2016). Owing to the lack of density data for most species and all these variables affecting densities we provide only general descriptive density estimates for each predator species (Table 9.2).

From the above, it can generally be concluded that predator density will most often be determined by prey density (coupled with various other factors). As such, we can also speculate that high natural prey biomass would ultimately also facilitate high livestock biomass (at least if both could co-occur). Under such conditions, we can further hypothesise that predator predation on livestock can be low when natural prey is high, possibly mediated through apparent facilitation (e.g. at high livestock and natural prey, predators will choose natural prey. Alternatively, high natural prey (and hence high predator density) can induce high livestock predation, mediated through apparent competition. While studies investigating the relationship between predator density and livestock predation is severely limited in South Africa, the pattern from elsewhere is not clear. Several studies have shown that high natural prey densities can sustain higher predator densities, but with an increased risk of livestock predation (and more conflict). In contrast, several studies have highlighted that increased natural prey decreased predation on livestock (Meriggi *et al.* 1996, 2011). However, many of these studies do not report on predator densities, which can be the driving factor in a variation of livestock predation and prey densities.

Dispersal of predators in South Africa

Dispersal occurs for a number of reasons. A dispersing individual is often alone, hungry, young and relatively inexperienced, out of its place and can go a long way out of its normal familiar range. These are dispersers perhaps who have left their mother's, prides or packs and looking to set up a new home. Alternatively, dispersers could be old, weak and hungry individuals who have been pushed out of prides, packs or territories. All these individuals can be responsible for important predation on livestock because it is easier than preying on wild prey.

Movement of predators through space and time is influenced by several factors that include availability or quality of food resources, predator avoidance and other environmental conditions, which will enhance their capacity to survive (van Moorter *et al.*, 2013; Kubiczek *et al.*, 2014). The way animals move and use space has an impact on interactions with resources, thus affecting ecosystem processes, e.g. when and where predation happens (Böhm *et al*., 2011). We, therefore, need to know what populations of predators are where. From this, we can perhaps predict dispersal patterns and mitigate against them. For instance, African wild dogs disperse, often from protected areas, in a predictable manner to form new packs. Pre-empting this with community engagement programs is therefore recommended (Gusset *et al.* 2007).

Many predators can move over large distances, especially when dispersing. An example of this is African wild dogs which have on multiple times been recorded dispersing over 80 km (Davies-Mostert *et al.,* 2012). These African wild dogs moved through protected areas, farmland, and communal living areas and along roads. All these situations, including private protected areas, provide opportunities for conflict.

Geographical distribution of livestock predation events in South Africa

Black-backed jackals and caracals are the main predators of livestock throughout South Africa, which can be attributed to the loss of large predators (leading to the release of mesopredators) and the variability in occurrence and abundance of other medium-sized and smaller predator species across the country (Yarnell *et al.*, 2013). There is no database on, and few data on, the distribution of livestock predation events within South Africa (Minnie *et al.*, 2015). Even within individual provinces, there are no published data available. We can therefore only provide a brief overview for each province. The type of livestock farmed influences the type of predator most likely to attack; larger predators are known for taking large domestic species, whereas smaller predators take a greater proportion of small to medium livestock, such as sheep and goats (Sangay & Vernes, 2008). This suggests that the type of livestock being farmed would be important in determining the geographic distribution of predation events. **[INSERT PARAGRAPH FROM ADDENDUM]**

In the Eastern Cape province, there are some data on vegetation-type specific predation by leopards in the Baviaanskloof Mega-Reserve (Minnie *et al*., 2015). Here leopards were reported to prey on sheep and goats. Verreaux's eagles (*Aquila verreauxii*) are also implicated in the killing of lambs, but direct evidence of this is often lacking (Visagie & Botha, 2015). During periods of extreme drought, Cape vultures (*Gyps coprotheres)* have been reported killing newborn lambs in a weak condition, particularly if ewes leave them alone, and African crowned eagles (*Stephanoaetus coronatus*) can come into conflict with stock farmers (Hodkinson *et al.*, 2007).

Van Niekerk (2010) conducted a study on the economic losses attributed to small stock predators in the Western Cape province and concluded that although predation losses were relatively low for the whole province, areas such as the Central Karoo, where small stock farming is the main agricultural activity, experienced high losses due to predation by black-backed jackals, caracals, leopards, chacma baboons, crows and vagrant dogs. Braczkowski *et al.* (2012) studied the diet of caracal in the George and Vleesbaai regions, and reported that although no livestock were detected in the scats of this predator, CapeNature had reportedly issued approximately 60 hunting permits for caracal to farmers in the Vleesbaai regions, suggesting that caracal-livestock conflict existed, even though not formally recorded.

In Mpumalanga province, Chardonnet *et al.* (2010) reported that occupants of some villages bordering the Kruger National Park (Mpumalanga and Limpopo) were responsible for the killing of lions that were supposedly responsible for killing cattle. To rectify the matter, it sufficed that the villagers remove cattle within 500 m of the fence. Van Niekerk (2010) reported that farmers in Mpumalanga attributed livestock losses to predation by black-backed jackals and caracals.

Personal communications from officials within the Gauteng Department of Agriculture and Rural Development (GDARD) to L. Dumalisile revealed that very few predator-livestock conflict events were reported by farmers in the Gauteng province; only through permit applications for hunting Damage Causing Animals (DCA's) are records of conflicts received. As a result of this, there is no reliable data on predator-livestock conflicts, except for some unconfirmed complaints from some farmers received by the General Investigations Unit of the Department that reported unconfirmed leopard kills (L. Lotter. pers. com. 2017).

In North West province, Thorn *et al.* (2012) reported that farmers attributed 20% of predation to caracals, 41% to jackals, 15% to leopards, 12% to brown hyenas, 7% to cheetahs, 3% to spotted hyenas, with one attack being attributed to servals.

Rowe-Rowe (1992) provided some information on predation in KwaZulu-Natal. He listed African wild dogs emanating from Hluhluwe-iMfolozi Park as an occupational source of livestock predation. Incidents of predation on sheep and calves by brown hyena have been reported from the Dundee, Estcourt, and Utrecht districts in KwaZulu-Natal. Predation on cattle calves and goats by spotted hyenas are common in northern KwaZulu-Natal around the Hluhluwe and Mkuze area adjacent to major reserves such as Hluhluwe-iMfolozi Park, Mkuze Game Reserve, and Phinda Private Game Reserve. Retaliatory hunting of spotted hyenas through trophy hunting has increased dramatically in the last nine years, potentially causing edge-effect related population declines within protected conservation areas (Hunnicutt, pers. obs. 2017). Lions that leave protected areas often kill livestock. Ezemvelo KZN Wildlife assists in destroying such problem lions if needed. Leopards occasionally kill livestock in KwaZulu-Natal.

In the Northern Cape province, Jansen (2016) reported that leopards were the main predators of goats near Namaqualand National Park. Another study in the Namaqualand (Paulshoek) found that apart from black-backed jackals and caracals, Cape foxes, Verreaux's eagles, black crows (*Corvus capensis*), leopards, chacma baboons, African wild cats (*Felis silvestris*), peregrine falcons (*Falco peregrinus*), spotted eagle-owls (*Bubo bubo*) and bat-eared foxes (*Otocyon megalotis*) were responsible for livestock losses (Lutchminarayan, 2014). Cape and lappet-faced vultures (*Torgos tracheliotus*) may sometimes kill newborn lambs, particularly if ewes leave these alone and exposed, and Verreaux's and martial eagles (*Polemaetus bellicosus*) sometimes come into conflict with stock farmers in the Northern Cape (Hodkinson *et al.*, 2007).

In Limpopo province, leopards remain the most important predator in livestock and game farming conflict (Pitman *et al.*, 2017). For example, leopards accounted for 68% of permits issued to nuisance wildlife in Limpopo province during 2003-2012 (Pitman *et al.,* 2017). Permits issued for other nuisance carnivores during 2003-2012 include brown hyenas (3%), black-backed jackals (2%), caracals (2%), cheetahs (0.5%), and spotted hyenas (0.5%) (Pitman *et al.,* 2017). The majority of leopard mortality events due to problem animal removal were often in prime leopard habitat (Pitman *et al*., 2015), which poses a conservation concern to leopard population persistence and connectivity (Swanepoel *et al.,* 2014; Pitman *et al.,* 2017).

Most predator-livestock conflicts recorded for the Free State involve predation by black-backed jackals and caracals (e.g. van Niekerk, 2010).

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SELECTED SPECIES ACCOUNTS:

As discussed above many species contribute to livestock predation in South Africa. While lion, African wild dog and spotted hyena predation may be restricted to the edge of protected areas and therefore remain relatively limited in South Africa, species like leopards, cheetahs, brown hyenas and chacma baboons can locally strongly contribute to livestock losses. In this section, we review the ecology of those predators in the context of livestock predation. Because only anecdotal evidence exists for the other species incriminated by South African farmers, they will only be briefly reviewed here and summarised further in Table 9.1.

Lion

The preferred prey species of lions are generally divided into three categories based on body weight: small, ≤100 kg – warthog (*Phacochoerus africanus*) and impala (*Aepyceros melampus*); medium, 100-230 kg for example blue wildebeest (*Connochaetes taurinus*), greater kudu (*Tragelaphus strepsiceros*) and plains zebra; and large, ≥230 kg for example buffalo (*Syncerus caffer*) and eland (*Tragelaphus oryx*). Water-dependent grazers tend to remain near open surface water during the dry season. This is associated with the moisture content of forage, which is typically low during that period, and thus restricts the ability to obtain water through foraging. These two factors directly drive the distribution of herbivores and their utilisation of landscapes, particularly water-dependent grazers (Smit *et al.*, 2007). Wildebeests and plains zebras are water dependent grazers that are spatially and temporarily influenced by surface water. Rainfall patterns in savanna systems have direct impact not only on the available surface water but also on vegetation growth (du Toit, 2010). Thus, when rainfall patterns change the distribution of plains zebras and wildebeests will be affected by available graze. Browsers obtain most moisture from their diet, thus making them water independent. Consequently, due to the feeding behaviour of browsers in savanna woodlands, the rate of encounter with lions is reduced.

In South Africa, the rate of livestock offtake by lions is relatively low in comparison to other African countries. This in part is due to the fencing policies and strict adherence to regulations in South Africa. Natural populations of lions are found in the Kgalagadi Transfrontier Park and Kruger National Park where incidences of lion and livestock interactions are reported beyond the national park boundaries (e.g. Funston 2011). This is often a consequence of dispersal within the protected area in conjunction with livestock foraging in proximity to the boundary fences. In other protected areas lions are actively managed (Miller *et al.*, 2013). In such places, the quantity and quality of resources are actively controlled to sustain lion populations. In so doing, this limits the likelihood of lion and livestock interactions.

Lions are nocturnal with two peak activity periods, at dusk and dawn. During daylight, lions rest and digest making them seldom active. Other predators adjust their activity to avoid competition with this apex predator. Similarly, prey species adapt their behavioural patterns according to lion peak activity time (Saleni *et al.,* 2007). In regards to livestock practices, having animals in corrals between dusk and dawn reduces the likelihood of predation by lions.

In addition to ecological factors, social dynamics also influences lion home range metrics to varying degrees. The home ranges of large prides in optimal patches may be smaller than expected, and the converse may be true for smaller prides in less productive areas. Thus, the number of adult females within a pride seems to influence the quality of the territory and may influence its relative size. Finally, anthropogenic influences could influence the movements and thus home ranges of lions. For example, mortalities due to human-lion conflict (Packer *et al.,* 2005), trophy hunting (Davidson *et al.*, 2011) and bushmeat snaring (Lindsey & Bento, 2012) could all influence home range size.

Movement along the landscape by predators varies according to the social structure and interactions with other members of the same species. In regards to lions, both male and female sub-adults leave or are chased out of the pride due to social pressures. Young sub-adult females disperse from a territory when the pride social structure becomes unstable, such as when resources are constrained. The prey size must facilitate proportionally or a greater metabolic return to the individual and pride. This can be accomplished when hunting in an optimal group size to maximise energy returns. Therefore when the number of adults results in lowered energetic returns, the sub-adult females are then pushed out of the pride. Sub-adult males, however, disperse or are driven out of the pride for reproductive and genetic reasons. Although this behaviour is natural, this can become challenging to management on small reserves or areas that are surrounded by human communities and livestock activity. For this reason, it is critical for reserve management to practice good reproductive management in the form of contraceptive implants and relocating sub-adults.

As human densities increase outside of protected areas and game farms, the greater the likelihood of prey depletion for the lions. Often this is a consequence of poaching and general illegal offtake of lion main prey species. The location of the protected areas and game farms that are large enough and able to sustain lions are often marginalised land that is unproductive for agriculture and intensive livestock breeding. As a result of this, the types of land use on the neighbouring properties are usually informal or small-scale livestock. Increasingly, however, the neighbouring areas are communities with high human population densities.

Lion and livestock interactions in South Africa are minimal. However, in areas such as the Kalahari temperatures influence the movement and activities of large livestock which are released to forage during the cooler evening hours. Not only temperature influences foraging behaviour, but also the mist that brings moisture in the night. This allows large livestock to forage across a wider landscape thus making them more vulnerable to predation. Smaller livestock are less vulnerable because of corralling.

The determination of the lion population in small areas is the number and quality of water points, prey availability and the size of the fenced area. There are some requirements in place for sustaining a lion population in protected and non-protected areas such as game farms: the size of the area, the landscape and the available resources. When appropriately managed, lions are seldom culprits of livestock offtake in South Africa.

Spotted hyena

Spotted hyena clans live in a “fission-fusion” society in which members often travel and hunt alone or in smaller groups, joining a clan only to defend the territory and a communal den site, or to hunt larger prey species (Smith *et al.*, 2007). The core of a spotted hyena clan is composed of at least one matrilineal group composed of closely related females and their offspring (Kruuk, 1972). Males disperse from the clan at sexual maturity between the ages of two and six years and will try to join non-natal clans as immigrants (Smale *et al*., 1997; Boydston *et al*., 2005).

Spotted hyenas are territorial, using vocal displays, scent marking, latrine sites, and border patrols to establish and defend territories (Kruuk, 1972; East & Hofer, 1993; Mills & Hofer, 1998). Territory size can vary based on prey densities, from 40 km^2 in the Ngorongoro Crater in Tanzania (Kruuk, 1972) to 1000 km^2 in parts of the Kalahari (Mills, 1990). Individuals are not limited to their clan's territory and often make long-distance foraging trips to find food (East & Hofer, 1993).

Despite a lasting stigma on this species as being a lowly scavenger, spotted hyenas are in fact efficient hunters able to kill animals several times their size, with a success rate of 25-35% (Kruuk, 1972; Mills, 1990). In ecosystems with high prey densities, such as the Maasai Mara in Kenya, hyenas have been recorded killing as much as 95% of the food they eat (Cooper *et al.*, 1999). Spotted hyena mostly consumes medium to large ungulates weighing up to 350 kg. However, they are also capable of effectively hunting sizeable animals such as giraffe (*Giraffa camelopardalis giraffa*) and Cape buffalo (*Syncerus caffer*) (Kruuk, 1972; Cooper, 1990; East & Hofer, 1993; Holekamp *et al.,* 1997).

As opportunistic hunters, spotted hyenas tend to hunt the most abundant prey species and do so either solo or in groups (Kruuk, 1972; Cooper, 1990; Höner *et al.*, 2005). In addition to hunting, spotted hyenas can utilise carrion for food (Kruuk, 1972; Cooper, 1990; Mills, 1990; East & Hofer, 1993). In areas where prey densities are much higher, the cost of carrion consumption was shown to outweigh the benefits and this feeding strategy is underutilised by spotted hyenas compared to other areas with lower prey densities (Cooper *et al.*, 1999). However, in areas where native prey species have largely been extirpated or displaced by extensive human settlements, such as northern Ethiopia, spotted hyenas can exclusively utilise anthropogenic food leftovers (Yirga *et al.*, 2012).

Limited work has been done to quantify livestock conflict with spotted hyenas in South Africa. However, much like leopards, they are commonly found outside of protected areas. Spotted hyenas have been recorded to utilise livestock such as cattle and goats in areas adjacent to protected parks with spotted hyena populations in KwaZulu-Natal (Mills & Hofer, 1998; A. Hunnicutt pers. obs. 2017). Though spotted hyenas are known to kill livestock, they are also often wrongly accused and persecuted due to their nature to also scavenge on carcasses of livestock predated by other carnivores. This has led to the common wrongful persecution of spotted hyenas by poisoning carcasses of livestock killed by other species (Mills & Hofer, 1998; Holekamp & Dloniak, 2010).

Despite the lack of work done in South Africa on livestock conflict, many studies in East Africa have investigated spotted hyena interactions with domestic animals. A study from the Maasai Steppe in Tanzania showed that spotted hyenas and leopards favoured smaller livestock such as goats, sheep, and calves (also dogs), whereas lions select cattle and donkeys (Kissui, 2008). Temporal patterns of attacks showed that lions were more likely to attack grazing animals during daylight, whereas spotted hyenas and leopards were almost exclusively predating at night. Slight seasonal variations were exhibited by lions and spotted hyenas, where attacks on livestock from both species increased during the wet season (perhaps when spotted hyenas would be shifting territorial patterns and moving longer distances daily, thus increasing the chances of encountering livestock) (Kissui, 2008).

Leopard

Leopards have the widest geographic distribution of all felids and achieve this by their adaptability (Boitani *et al.*, 1999) and varied diet (Hayward *et al.*, 2006a). They are solitar and associated with rocky hills, mountains and forests, but they also occur in deserts where they are restricted to the moist watercourses (Nowell & Jackson, 1996). In desert-like environments, leopards get moisture from the prey they consume (Bothma 2005). Leopards inhabit large parts outside formal conservation areas in South Africa (Swanepoel, 2008). Conflict between leopards and ranchers is common in livestock and game ranching areas, often resulting in persecution. This is made worse by their large home ranges which range from 159 to 354 Km^2 or larger (Swanepoel, 2008). Negative attitudes towards leopards, caused by anti-predator sentiments and leopards preying on livestock and game are normally the reason for leopard persecution (Swanepoel, 2008).

Estimates of livestock in predator diets (based on scat analysis and GPS cluster located kills) appears to be species and region specific (for reasons discussed above). The leopard in the most widespread large carnivore in South Africa and is often found on non-protected areas (Swanepoel *et al.*, 2012), and so several studies have investigated leopard diet (Balme *et al.*, 2014). In the Soutpansberg area (Vhembe Biosphere, North South Africa) several dietary studies have found no livestock in leopard diet (Stuart & Stuart, 1993; Schwarz & Fischer, 2006; Chase Grey *et al.*, 2017), despite the fact that livestock are highly abundant in these areas (Chase-Grey, 2011). In contrast some studies from the Waterberg area, South Africa, have found that livestock (essentially cattle) contributed to between 2.5% and 3.9% of leopard diet (Grimbeek, 1992), while Pitman *et al.* (2013), Jooste *et al.* (2012), and Swanepoel (2008) failed to detect any livestock in Waterberg leopard diet. In areas where small ruminants dominate livestock (e.g. goats and sheep; Western Cape), leopards appear to incorporate livestock more often into their diet, especially in areas where native prey animals were depleted (Mann, 2014; Jansen, 2016). For example in the little Karoo (Western Cape) livestock (mainly goats, cattle and feral donkeys) contributed to 10% of prey biomass consumed by leopards (Mann, 2014). In the Namaqualand, there was a stark contrast between leopard diet in protected areas (livestock 3.5% of biomass consumed, mainly goats) compared to farmland (livestock 40.4% biomass consumed with 22.8% goats and 14.8% sheep) (Jansen, 2016). In the Cederberg area livestock comprised around 3.5% to 3.8% of leopard diet (Martins, 2010; Martins *et al.*, 2011).

African wild dog

African wild dogs are endangered, with a population estimate of 6600, of which 1400 are considered mature individuals (Woodroffe & Sillero-Zubiri, 2012). Free-living populations have declined markedly over the past several decades with limited populations surviving in South Africa (Davies-Mostert *et al.*, 2009). African wild dog numbers are limited by competition with larger, more abundant carnivores, but are still at low densities outside protected areas owing to direct human persecution. The diets of African wild dogs and spotted hyenas overlap extensively, and there is a negative correlation between African wild dog and hyena densities in some large conservation areas. The latter also applies to African wild dogs and lions. Lions are also responsible for a large percentage (sometimes up to 50%) of African wild dog mortalities in some areas.

Livestock predation by African wild dogs is low. However, it can be locally severe with surplus killing (WAG-SA minutes). For example, in Kenya in areas with abundant livestock African wild dog predation was found to be low (*ca* one attack per 1000 km^2 per year), and the costs of tolerating the African wild dogs were low (US $3.40/African wild dog/year), even where there were low densities of wild prey (Woodroffe *et al.,* 2005). The same has been found in farmland in the Waterberg area in South Africa where the diet of African wild dogs was determined through scat analysis. No livestock remains were found in the scats, despite some of the scats being collected on livestock farms (Ramnanan *et al.*, 2013). In Botswana, Gusset *et al.* (2009) using questionnaires found African wild dogs responsible for 2% of reported cases of predation. Here, two resident packs did not correspond to the expected conflict (Gusset *et al.*, 2009). Despite this, ranchers interviewed in South Africa and Zimbabwe ranked African wild dogs as the least liked predator, disliked even more than spotted hyenas, jackals, lions and leopards (Lindsey *et al.*, 2005b). Although African wild dogs kill livestock at lower levels than some other predators, they are still killed in retaliation for incidents of depredation (Fraser-Celin *et al.*, 2017).

Chacma baboons

Baboons (*Papio* spp.) are large and widely spread primates that inhabit various habitats, even heavily encroached by human activities, thanks to their diet flexibility, agility and cleverness (Altmann & Altmann, 1970; Swedell, 2011). While chacma baboons are generalist omnivores that will include in their diet a wide range of food sources depending on their availability, they are also highly selective and will favour nutrient-rich food when available (Hamilton *et al.*, 1978). Predatory behaviour and vertebrate meat consumption of wild prey have been described in many primates species, including chacma baboons and related olive baboons (*Papio anubis*) with various intensity across Africa (Strum, 1975; Hausfater, 1976; Hamilton & Busse, 1978; Strum, 1981; Davies & Cowlishaw, 1996). Vertebrate prey species include various small ungulates, such as Thomson's gazelles (*Gazella thomsoni*), Grant's gazelles (*Gazella granti*), dikdiks (*Rhyncotragus kirki*), steenboks (*Raphicerus campestris*), impalas (*Aepyceros melampus*), other primates (e.g. vervet monkeys, *Cercopithecus aethiops*), small mammals (African hares, *Lepus capensis*, and several rodent species), birds, reptiles and amphibians. Prey are encountered by chance while foraging and shortly chased and seized, but a few cases of "active" hunting behaviour have been observed (Hausfater, 1976; Harding 1973; Strum, 1981). Strum (1981) found that the total number of prey killed in her focal troop varied from 16 to 100 per year, during a 7 year monitoring in Kenya. However, meat represents an anecdotal portion of baboons diet while more than 80% of their diet is made of various plant parts, including grasses, leaves, seeds, fruits, flowers, roots and bulbs (Hamilton & Busse, 1978; Ambrose & Deniro, 1986; Codron *et al.*, 2006; Strum, 2010).

Baboon predation on livestock is seldom documented in scientific literature, but South African farmers' reports mainly concern small livestock like young sheep and goats (Dart, 1963; Stoltz & Saayman, 1970). Butler (2000) surveyed Gokwe communal farmers for livestock losses in Zimbabwe and found that chacma baboons were responsible for more kills than lions and leopards (52% kills attributed to chacma baboons representing about 125 kills over 3.5 years, mainly young goats). A more recent survey in Central Karoo farms in South Africa revealed that since the year 2000 a small but an increasing number of farmers also rank chacma baboons as the top predator of small livestock on their farms, ahead of the two larger carnivore species in the area (i.e. jackals and caracals) (Tafani *et al.*, in prep). Prey were mostly lambs, and carcasses were identifiable with their stomach ripped open, and the skin rolled up (Tafani & O'Riain, 2017; see also Strum, 1981 in Kenya). Tafani *et al.* (in prep) found less than 5% of faunivory (wild and domestic) in the yearly diet of most individuals of at least two different troops ranging on small-livestock farms. Meat-eating seemed to contribute little to chacma baboon diet, and adult males showed significantly higher proportions of meat in their diet than females (Tafani *et al.*, in prep), which concurs with Butler (2000) observations of only adult males predating livestock.

Various ecological characteristics of baboons can be responsible for variations in raiding behaviour and meat-eating, but a lot of uncertainty exists about their respective contribution to predation. Eating more protein may benefit both sexes through faster growth and heavier adult weights (Strum, 2010), and increase female reproductive success through shorter interbirth-interval (Strum, 2010). However, despite baboons complex social structure, no direct link was observed between dominance rank and raiding behaviour or meat consumption rates (Strum *et al.*, 1981; Strum *et al*., 2010). Additionally, compared to apes, prey sharing is limited and often an involuntary result of agonistic interactions. Therefore, predatory behaviour is very variable between individuals and between troops. Various studies showed that mainly adult males (Strum, 1981; Hamilton & Busse, 1978; Strum, 1975; Hausfater, 1976; Davies & Cowlishaw, 1996; Butler, 2000) were involved in predation of both wild and domestic prey; and males were the only ones initiating complex hunting techniques (Strum 1981). Between individual interest and propensity to hunt are also primarily due to skills and personality (Strum [1981] in baboons; Oelze *et al*. [2011] and Fahy *et al*. [2013] in apes), restricting this behaviour to few individuals. However, it is important to note that behaviour acquisition through learning may happen between individuals of the same troop, and Strum (1981) studied the case in Gilgil, where a focal group of olive baboons steadily increased hunting activities with time (between 1971 and 1973) from a mainly male dominated activity to a widespread behaviour among all individuals of the troop apart from infants.

Baboons can learn quickly about the spatiotemporal availability of new food sources in their territory and its vicinity (Strum, 2010); the availability of human food was found to decrease daily path length and home range size of raiding troops (Strum, 2010; Hoffman & O'Riain, 2012). But initiating and fulfilling a kill may also come at a cost regarding energy expenditure and exposure to risk (from farmers or predators like leopards); baboons may thus only initiate a raid if the benefits exceed the risk (Strum, 2010). The increase in raiding and predation rates are for example mainly observed in low biomass conditions, often associated with drought in the African continent (Butler, 2000; Strum, 2010; Tafani *et al*., in prep). Most South African small-livestock farms are susceptible to droughts, and rely on the provision of artificial water points (farm boreholes) where supplementary feed may be provided for livestock during veld food scarcity; this may strongly increase farm attractiveness for chacma baboons during those periods (Tafani & O'Riain, 2017).

Chacma baboons are often difficult to deter due to their ability to habituate to many techniques (Kaplan & O'Riain, 2015; Felhman *et al*., 2017; see PredSA Management Chapter). However, currently, due to the lack of knowledge and legal framework, chacma baboons are culled indiscriminately and in high numbers by farmers (Tafani & O'Riain, 2017). While more research on livestock predation by chacma baboons is needed, a better protection of livestock during critical periods of low biomass and lambing peaks could reduce chacma baboon raiding success. Additionally, as new raiders are still responsive to management, identifying and classifying the raiders (generally adult males), as proposed by Strum (2010), into traditional raiders, naïve newcomers or those in-between, would allow for case-specific management.

Birds of prey and vultures

Some raptors are known to predate occasionally on livestock (with a low conflict potential); lappet-faced- and Cape vultures may kill newborn lambs, particularly if left alone (Hodkinson *et al*., 2007).

Verreaux's Eagles, especially immature birds, are known to take the lambs of smaller livestock (e.g. sheep and goats) and antelope as food (Hodkinson *et al*., 2007). This can lead to conflict with small-stock owners in areas where the eagle's natural prey base has been reduced, and they have to look for alternative food sources. Reports of such incidents reach fieldworkers regularly, especially during the drier months when the eagles are breeding. Several incidents of direct persecution of these eagles have been recorded over the years. Verreaux's eagles regularly take carrion and are consequently often wrongly accused of killing livestock which were, in fact, killed by other predators or have died of natural causes (Botha, 2012).

In addition to Verreaux's Eagles, other species such as martial and African crowned eagles have been reported killing livestock and certainly can do so, but many cases lack substantive evidence. Similar to the abovementioned scenario with Verreaux's eagle, these birds readily scavenge and can be wrongly accused of killing livestock when they are observed scavenging from a carcass (Visagie & Botha, 2015). This may also apply to species such as the tawny eagle (*Aquila rapax*), African fish eagle (*Haliaeetus vocifer*), jackal buzzard (*Buteo rufofuscus*) and yellow-billed kite (*Milvus aegyptius*) who all readily scavenge from carcasses.

IDENTIFICATION OF RESEARCH CHALLENGES AND GAPS

In this assessment, we have highlighted several ecological, sociological and economic factors that can affect livestock predation by other large predators. We now mention several challenges and research gaps that became evident during this exercise and make some recommendations to address these.

1) There is a lack of a coherent predator conflict monitoring program across all provinces. We found few published data on predator conflict as recorded by the relevant provincial authorities. As such it is difficult to quantify temporal and spatial trends in predator conflict. We suggest that possible avenues to address these are for provincial authorities to liaise with local academic institutions to develop and maintain relevant monitoring programs.
2) Predator research is still predominantly carried out in protected areas. For predator research to be relevant, it will have to be framed in the broader conservation issues faced by predators. Since the majority of predators in South Africa require large tracts of land and the majority of suitable habitat is often in private hands, it is essential to increase research in these non-protected landscapes. Furthermore, the dominant determinant of predator survival in non-protected areas is human wildlife conflict and tolerance; it is essential that research address these issues.
3) Controlled treatment studies investigating the effectiveness of mitigation actions is needed. There is a general lack of research investigating the effectiveness of mitigation actions. These controlled treatment studies will be fundamental in advancing conservation actions in non-protected areas.
4) Basic empirical data needs to be collected on predation events. The location, size, sex and species of prey and predator are required. Along with this, the density of predators needs to be determined. There are limited data on densities of African wild dogs, cheetahs and leopards in some areas but not sufficiently accurate to determine livestock predation risk. Some livestock predation data may be available through permit offices which should be analysed and published. A risk model of livestock predation by predators based on environmental and livestock management variables (or any other variables that can be identified), which allows for identification of high-

risk zones to define mitigation strategies (e.g. Zarco-González *et al.*, 2013; Zingaro & Boitani, 2017) could be generated.

5) More basic knowledge (including movements, range, behaviour, prey availability) is needed for most species, especially outside protected areas, where they come into contact with people and livestock. Deterrent techniques or mitigation methods would ultimately need to be developed and trialled for those predators, to avoid the often illegal or disproportionate retaliation levels against them compared to their actual impact on livestock.

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Table 9.1. Predators (excluding black-backed jackal and caracal) implicated in livestock predation in South Africa.

Species	Species predated	Evidence	Frequency	Financial implications	Main activity time	Source of information
Leopard	Cattle, sheep, goats	Strong	Common	Local, isolated but can be substantial	Mostly nocturnal	Norton *et al.*, 1986; Swanepoel, 2008; Martins *et al.*, 2011; Minnie *et al.*, 2015; Hayward & Slotow, 2009
Lion	Cattle, sheep, donkeys, horses	Strong	When out of protected area - rare	Local, isolated but can be substantial	Nocturnal and crepuscular	Hayward & Slotow, 2009; Butler, 2000
Cheetah	Cattle, sheep	Strong	Rare in SA	Local, isolated but can be substantial	Diurnal, crepuscular activity pattern with 62% diurnal	K. Marnewick pers. com. 2017; Wilson, 2006.
Serval	Sheep	Weak	Rare	Low	Nocturnal and crepuscular	Thorn *et al.*, 2012; Griffiths *et al.*, 2017
African wild cat	Sheep, goats (juveniles)	Strong	Rare	Low		Smuts 2008; Lutchminarayan, 2014
Black-footed cat	?	?	?	?	Nocturnal	Nothing found?
Spotted hyena	Cattle, goats	Strong	Rare	Low, but can be locally substantial	Nocturnal but flexible	Parker *et al.,* 2014

Brown hyena	Goats	Strong	Rare	Low	Nocturnal	Mills, 1990
Aardwolf	carcasses of various species	Weak	Rare	Low	Nocturnal but flexible	Anderson, 2013
African wild dog	Sheep, goats, seldom cattle	Strong	Rare	Local, isolated but can be substantial	Strictly crepuscular	Davies-Mostert & Du Toit, 2004; Lyamuya *et al.*, 2014, Woodroffe *et al.*, 2005; Hayward & Slotow, 2009
Domestic dog	Sheep, goats, seldom cattle, mostly scavenge	Strong	Unknown	Low	Mostly diurnal	Butler & Toit, 2002; Lutchminarayan, 2014
Cape fox	Sheep, goats	Strong	Rare	Low	Nocturnal	Stuart, 1982; Bester, 1982; Edwards *et al.,* 2015; Daviet-Mostert *et al.,* 2007
Bat-eared fox	None found?	?	Rare if true	Low if true	Crepuscular and nocturnal	Edwards *et al.,* 2015; Lutchminarayan, 2014
Honey badger	Sheep	Strong	Rare	Low	Nocturnal but flexible	Begg *et al.*, 2016; Do Linh San *et al.*, 2016; PMF, 2016
African clawless otter	Sheep	?	Rare	Low	Nocturnal to crepuscular in places	Anecdotes; PMF, 2016

Chacma baboon	Goats, sheep	Strong	Rare to locally abundant (see Butler 2000, for Zimbabwe)	Local, occasional but can be substantial and adds to infrastructure or crop damages	Diurnal	Bolwig, 1959; Hall, 1962; Dart, 1963; Butler, 2000; Tafani *et al.*, in prep.
Bushpig	Sheep	?	Rare	Low	Nocturnal	Seydack, 1990; PMF, 2016
Birds (eagles, owls, corvids, gulls)	Sheep, goats		Rare	Low	Diurnal or nocturnal (owls)	Davies 1999; Botha, 2012; Lutchminarayan, 2014; Visagie & Botha, 2015; PMF, 2016
Python	Calves, goats, dogs	Strong	Rare	Rare	Diurnal	Hodkinson *et al.*, 2007
Crocodiles	Sheep, goats, donkeys, dogs	Strong	Rare and localised	Low but can be severe for poor communities		Guggisberg, 1972; Fergusson, 2000

- Strong = supported by recognised peer reviewed publications or reviews by credible sources,
- Weak = not supported by peer reviewed publications or reviews by credible sources, some anecdotes
- Common = published data showing frequent reports as indicated in publications or expert opinion.
- Rare = no data showing frequent occurrences of predation. Evidence through anecdotes.

Table 9.2. Characteristics of the social and spatial organisation of predator species implicated in livestock conflicts in South Africa (Skinner and Chimimba 2005).

Predator species	**Social organisation**	**Group size**	**Territorial**	**Home range sizes (km^2)**		**Density (ind./100 km^2)**
				Minimum	Maximum	
Leopard	Solitary	1-2	Yes	14.8	2182	6.1
Cheetah	Solitary females / male coalitions	1	Yes, males	24	1848	0.25-1
Serval	Solitary	1 or 1 + young	Yes	2.2	38	0.4-0.1
African wild cat	Solitary	1 or 1 + young	Yes	3.4	9.8	10-70
Lion	Group	1-30	Yes	150	4532	Up to 15
African wild dog	Group	1-50	Yes	150	>2000	Up to 60
Side-striped jackal	Group	1-7	Yes	0.2	4	0.07-1
Cape fox	Solitary	1-2	Yes, around den	9.2	27.7	
Feral domestic dogs	Solitary; group	?	?	1	4.6	?

Spotted hyena	Group	3 to 90+	Yes	9	>1000	2-35
Brown hyena	Solitary foragers	1 – 2	Yes	49	480	2-3
Chacma baboon	Group	10 to 200+	Yes	?	?	?
Honey badger	Solitary	1 or 1 + young	Yes	85	698	3-10
Bushpig	Group	1-5	Yes	3.8	10.1	3-50
Crocodile	Solitary	1	Yes	0.5	0.8	?

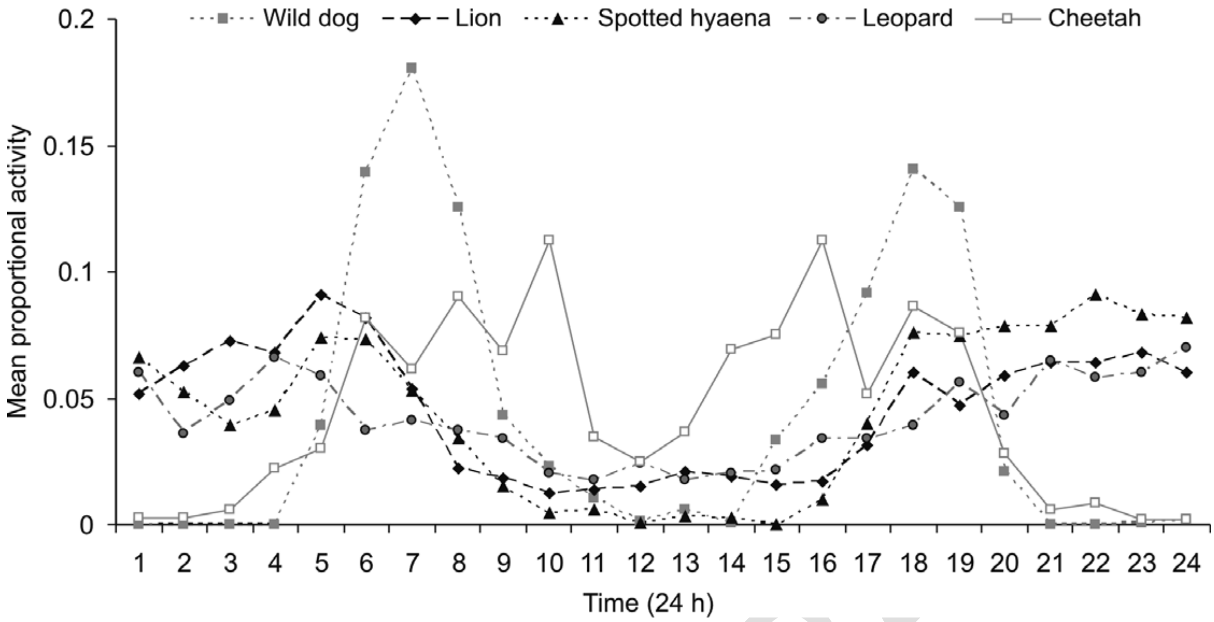

Fig. 9.1 Daily mean activity pattern (proportion an animal's daily activity that occurs in each hour) of all five members of Africa's large predator guild. (From Hayward & Slotow, 2009; Reproduced with permission of SAWMA).