Human-carnivore conflict over livestock:
the African wild dog in central Botswana

Matthew Swarner
U.C. Davis Graduate Group in Ecology

Large carnivore populations have declined worldwide in the last century (Ginsberg and Macdonald 1990, Nowell and Jackson 1996), primarily as a result of conflict with humans (Gittleman et al. 2001). Carnivores are implicated in a wide range of conflict types including human predation (Kruuk 2002), spread of disease (Guan et al. 2003), and competition for prey species with humans (Ginsberg 2001). Prey competition can be especially acute and emotive in the context of carnivores preying on farmed ungulates (Fritts et al. 2003). Depredation conflict has been shown to cause locally intense economic losses (Kruuk 2002), to prompt retaliatory killing directed at culpable carnivores (Ogada et al. 2003) as well as innocent ones (Sacks et al. 1999), and to exacerbate decline and inhibit recovery for several carnivore species (e.g., snow leopards: Mishra 1997, wolves: Mech and Boitani 2003). The consequences are dire: two species of predatory mammals involved in livestock depredation conflict, the Tasmanian wolf and the Falkland Island fox, have already gone extinct in the last two centuries (Woodroffe et al. *in prep*).

To avoid further extinctions, conservation biologists must work toward a better understanding of how carnivores can coexist with people. Population recovery, recolonization, or reintroduction schemes will not succeed unless the original cause of population decline has been eliminated or reduced (Reading and Clark 1996). For many large carnivore species, then, continued existence relies on mitigating livestock depredation. In this context, African wild dogs have been the focus of intensive conservation concern due a severe reduction in range, successive extinctions even in protected areas, and the endangered status of the remaining 3,000-5,000 individuals (Fanshawe et al. 1991, Woodroffe et al. 1997). Wild dogs have also been reported to prey on livestock wherever researchers have looked in or near human communities (Kenya: Woodroffe 2003; Namibia: Robin Lines, pers. comm.; South Africa: Lindsey 2003; Zimbabwe: Rasmussen 1999) and lethal control is a major factor contributing to the species' current population collapse (Woodroffe et al. 1997). In this paper, I review the natural history and current decline of wild dogs, discuss depredation behavior and strategies used to mitigate human-carnivore conflict, and finally, propose future directions and questions for my dissertation research.

Natural History. African wild dogs (*Lycaon pictus*) are members of the canid family, weighing 20-25 kg, and characterized by individually distinct patterns of white, black, and brown (Figure 1). As the sole representative of the genus *Lycaon*, wild dogs are only distantly related to jackals and Eurasian wolves and are neither feral domestic dogs nor hyenas. Wild dogs prey primarily on medium-sized antelope (50 kg), although they are capable of capturing ungulates as large as 200 kg when hunting cooperatively. Highly social, wild dogs occur in groups of up to 50 individuals, but more often as 4-8 adults plus juveniles and pups. Pack social structure consists of a dominant breeding pair, the pair's offspring from one or more litters, and additional adults typically related by sex (i.e. most females are closely related to each other, but not to the males). As a cooperative breeding species, all pack members aid in raising the litter by delivering food to the reproductive densite as well as providing anti-predator defense. Poor reproductive success by small groups suggests that a critical pack size of five or more adults may be required, on average, to successfully raise a litter (Courchamp and Macdonald 2001). Wild dogs range widely and in most ecosystems studied, exclusive territories encompass 400-700 km^2 (Woodroffe et al. 1997).

Decline and current status. Historically, African wild dogs occurred throughout sub-Saharan Africa, excluding rainforest and desert areas (Figure 2a; Fanshawe et al. 1991). Wild dogs no longer exist in 25 of 39 previously occupied countries and the species' distribution is currently highly fragmented (Figure 2b; Fanshawe et al. 1997). An estimated 3000-5000 wild dogs remain in Africa (Woodroffe and Ginsberg 1999). Placing this statistic in the context of other large African mammals, wild dogs are equal in abundance to black rhinos (~3000), more than twice as rare as cheetah (9000-12,000), and ~80 times less abundant than African elephants (290,000, Woodroffe and Ginsberg 1999). The World Conservation Union (IUCN) classified the wild dog as endangered in 1996 and subsequently identified causes of population decline in an Action Plan (Woodroffe et al. 1997).

Causes of decline. In the last century, wild dog populations declined across Africa and remain at risk of extinction due to multiple, often interrelated, factors (Table 1). Woodroffe and Ginsberg (1999) considered habitat loss and persecution to be the primary causes of both historic and current population decline, exacerbated by the species' wide-ranging behavior and low population densities. Wild dog densities are negatively correlated with lion and hyena densities across five studies (Creel and Creel 1996) and lion predation is the primary cause of natural mortality (Woodroffe and Ginsberg 1999). Wild dogs avoid areas heavily used by lions (Mills and Gorman 1997), which may limit the area available to wild dogs in reserves (van Dyk and Slotow 2003). Rabies and canine distemper outbreaks have also caused local extinction even in large protected areas (Woodroffe et al. 1997) and may be related to contact with domestic dogs.

Most wild dog populations number 50 individuals or less (see table 5.2, Woodroffe et al. 1997) and face a high likelihood of extinction due to environmental stochasticity and genetic processes. In addition, populations that inhabit small reserves (<3600 km^2) also suffer a greater extinction risk because small reserves tend to occur in areas of high human density with significantly more human-induced mortality for carnivores (Woodroffe and Ginsberg 1998, Harcourt et al. 2001). Human-induced mortality includes accidental killing by snares and roadkills as well as direct persecution.

The extermination of wild dogs in national parks and reserves was a management strategy as recently as the 1970s when managers treated predators as 'vermin' to be eradicated in favor of other wildlife species (Fanshawe et al. 1991). Persecution of wild dogs continues today, due in part to the widespread negative perception of wild dogs that was perpetuated and often misconstrued by early wildlife managers, but primarily because wild dogs are considered a threat to livestock (Fanshawe et al. 1991, Woodroffe and Ginsberg 1999). In 1997, the IUCN Canid Specialist Group released the African Wild Dog Action Plan (Woodroffe et al. 1997) assessing the species' current distribution and highlighting future research priorities to help stall the species' decline. Foremost among the priorities was applied research to resolve conflict between human and wild dogs. I propose that the mitigation of conflict between livestock producers and African wild dogs will require assessment of the problem, an understanding of the conditions in which depredation behavior occurs, the encouragement of practices that prevent depredation, and in some cases, increasing local tolerance of coexistence with carnivores.

Assessing depredation conflict. Assessment of livestock depredation varies across contexts and loss estimates differ according to the assumptions of total livestock numbers, extrapolation procedures, and economic value of lost livestock individuals (Knowlton et al. 1999). Typically, investigators respond to reported depredation events (Till and Knowlton 1983) or actively search for dead livestock (Sacks et al. 1999) and then examine the carcass for characteristic puncture wounds or other signs that indicate the predator species responsible.

The available evidence suggests that wild dogs rarely prey on livestock (Fuller and Kat 1990, Rasmussen 1996), but that livestock producers experience unevenly distributed and locally intense economic loss (Woodroffe and Ginsberg 1997). Although this appears to be a pattern common for most canids (Ginsberg and Macdonald 1990), the disproportionate attention that livestock depredation attracts compared to mortality due to weather or disease (Breitenmoser 1998) de-emphasizes the importance of its frequency. Perceived loss may overestimate documented loss (Rasmussen 1999) and thus, quantitative assessment and investigation is preferred to exclusive reliance on surveys of livestock producers.

In some African countries, problem animal control or other national wildlife agencies assess depredation events, but most available data typically comes from independent research. The Laikipia Predator Project examined historical records and interviewed managers and pastoralists to estimate depredation rates for commercial ranches and pastoralist groups in Kenya (Ogada et al. 2003). Annual losses were proportionally similar for both groups with 0.8-0.9% of cattle and 2.1-2.5% of sheep and goats lost to predators annually. Also in Kenya, Mizutani (1993) estimated that large carnivores killed 2.2% of available sheep. In northwest Zimbabwe, 2% of all cattle losses were attributed to wild dog predation (Rasmussen 1999). Despite low predation rates, total economic loss can be high. Lindsey (2003) estimated that conserving one pack of wild dogs on South African ranchland would cost $11,000-$55,000 per year (if livestock loss to predation estimates was compensated at full market value). Examples from other continents also indicate the high costs that can occur at individual and national levels. Livestock farmers in the Indian Himalaya lose an average 12% of livestock per family to snow leopards and other carnivores (Mishra 1997). On a larger scale, sheep producers in the U.S. lose an estimated $40-150 million annually to predators (Knowlton et al. 1999). Once the extent of depredation is assessed, research can contribute to the mitigation of conflict through an understanding of depredation behavior.

Understanding depredation behavior. The conditions in which carnivores exhibit depredation behavior is perhaps the most essential factor in understanding livestock conflict, let alone mitigating it. Published information on depredation by wild dogs is sparse (Rasmussen 1999) as is the case for African carnivores in general (although see Mizutani 1993, Ogada et al. 2003). Therefore, most of what we know about depredation behavior originates from the extensive literature on coyotes and wolves in North America and Europe (see reviews in Knowlton et al. 1999, Fritts et al. 2003). Depredation has been shown to vary with predator sex (Linnel et al. 1999), breeding status (Sacks et al. 1999), abundance (Thirgood et al. 2000), climatic variability (Bangs et al. 1998), management control method (Knowlton et al. 1999), and the presence, abundance, and reproductive season of native prey (Bangs et al. 1998, Sacks and Neale 2002, Treves et al. 2002).

A widely-held view suggests that certain demographic groups may be more likely to prey on livestock than others. In a review of livestock depredation studies, Linnel et al. (1999) found that males of solitary species do appear more likely than females to kill livestock. The authors attributed this male bias as a consequence of wider ranging movements or potentially bolder hunting behavior, such as seen in coyotes hunting native prey. In contrast, Linnel et al. (1999) found little conclusive evidence that inexperienced and/or dispersing juveniles or infirm adults kill disproportionately more livestock than other demographic groups. Till and Knowlton (1983) suggested that raising pups increase energetic demands such that breeding coyotes kill livestock more often in Wyoming, although depredation does not correlate with coyote breeding season in other areas (Blejwas et al. 2002). Likewise, the relationship between carnivore abundance and depredation rate is also mixed across studies. In Idaho, sheep depredation increased proportionally with coyote densities (Stoddart, unpub. data, in Knowlton et al. 1999), while many members of the coyote population were not involved in sheep depredation in other studies (Sacks et al. 1999). Linnel et al. (1999) questioned whether ‘problem’ individuals exist at all or if any carnivore exposed will prey on livestock. Understanding the relationship of predator population dynamics and livestock depredation remains unclear and data from African carnivores is sorely lacking.

Carnivores tend to prey more on domestic stock when wild prey populations are low and depredations can decrease after native prey is restored or rebounds (Fritts et al. 2003). For example, Sacks and Neale (2002) found no evidence that coyotes preyed on lambs more than deer when both prey species occurred in relative equal numbers on coyote territories, despite the fact that sheep are more energy efficient to capture and consume. In Idaho, sheep depredation spiked temporarily when the coyotes' primary native prey, the jackrabbit (*Lepus californicus*), population collapsed (Stoddart, unpub. data, in Knowlton et al. 1999). Also linked to prey availability, climatic variability can influence depredation behavior. In Montana, white-tailed deer populations were severely reduced during an atypically harsh winter in 1996 (Bangs et al. 1998) and in the subsequent year, wolves took record numbers of livestock. In support of this general pattern, the only study that observed the relationship of native prey to wild dog depredation documented livestock loss only where wild prey populations were severely reduced (Woodroffe 2003).

Preventing depredation. Management control methods also influence depredation behavior, but effectiveness varies according to the technique employed. Fortunately, a large motivation exists to encourage or develop successful deterrence strategies because preventing livestock depredation results in the two-fold benefit. First, livestock producers' economic losses are reduced and second, retaliatory persecution and carnivore mortality potentially decrease. Recent papers have reviewed deterrence studies including the effectiveness of some techniques (Cluff and Muray 1995, Shivik et al. 2003). Therefore, I summarize the methods in Table 2 with reference to its application in an African context.

Tolerating depredation. Depredation is infrequent and of lower magnitude compared to other sources of livestock mortality. Therefore, one strategy to mitigate conflict may be to increase local tolerance of the amount of depredation that does occur when carnivores exist in the landscape. Working in Ethiopia, Sillero-Zubiri and Laurenson (2001) suggested that recognizing the concerns of communities regarding carnivores and other wildlife improved local attitudes, even when the scale of the problem remained the same. Related benefits of carnivore conservation programs within communities include economic benefits through ecotourism or hunting, compensation for predator-related loss, and employment in research and conservation activities (Sillero-Zubiri and Laurenson 2001). However, the amount of depredation may have very little to do with how people feel about wild dogs. Woodroffe and Ginsberg (1999) wrote, "persecution of wild dogs is rarely a direct response to livestock loss: in most of Africa, wild dogs are shot or poisoned whenever they are encountered." Tolerating carnivores in the landscape and the depredation that sometimes accompanies that coexistence is a major challenge in an African context where economic losses, even when small, can be significant to small-scale producers and lethal control may be convenient, satisfying, and effective.

Wild dogs and livestock in Botswana. The northern Botswanan wild dog population (together with contiguous populations of wild dogs in Zimbabwe and Namibia) accounts for approximately 1200 individuals or 1/5-1/3 of the entire estimated population (Table 5.2 in Woodroffe et al. 1997). Operating since 1989 in the Okavango Delta and Moremi Game Reserve (Figure), the Botswana Wild Dog Research Project (BWDRP) continuously tracks life histories of individuals and spatial movements of packs with radio telemetry and GPS collars. Wild dogs in protected or otherwise non-livestock areas exhibit remarkable tolerance of human observation, allowing close recording of behavior and individual recognition. The ongoing BWDRP database contains hundreds of individuals, pack reproductive success, territory use, mortality data, and biannual prey census records (Ginsberg et al. 1995, McNutt and Boggs 1996, McNutt 1996).

However, the project has more limited information on wild dogs in other areas of Botswana such as the Central Kalahari Game Reserve, Nxai Pan National Park, and the matrix between these protected areas (Figure 3).

In 2002 and 2003, I worked to extend the current study site into Kalahari game and livestock ranching areas. Unsurprisingly, initial efforts confirmed the presence of wild dogs and that livestock-related conflict was occurring. Ranchers reported that wild dogs do prey on domestic stock, although less frequently than leopard or cheetah (lions have been exterminated from many of the livestock areas surveyed). A single farm attributed a $6,250 economic loss to wild dogs during an eight-month period in 2001. However, that ranch may have incurred exceptional losses due to wild dogs reproducing on their property during some of that period. In addition, one 2-year-old cow was confirmed in 2003 as a wild dog depredation due to spoor surrounding the kill (Figure 4). A pack of nine dogs was observed and the project is currently gathering reports and photos to identify where and how many packs are using ranching areas. Conflict with game ranching also emerged as a critical issue within the study area, involving predation on native ungulate prey that exist as valuable trophy animals within fenced areas. The relationship between game farmers and predator conflict is poorly studied, although conflict is likely to increase in Botswana as recent changes in European Union policy has made cattle farming less economical (see BBC). A strong negative view of wild dogs existed almost ubiquitously within the ranching community.

I propose to study wild dog depredation in the central farming region in Botswana where I conducted most of my initial survey work. Central Botswana contains multiple land-use patterns including commercial cattle farms, rural Matswana livestock outposts, game ranches, trophy hunting concessions, Nxai Pan National Park, and the Central Kalahari Game Reserve. My preliminary work has led to the formulation of a list of key research questions that I will examine during my dissertation work. In addition, I will describe aspects of wild dog natural history in a previously unstudied habitat.

Behavioral ecology of wild dogs in the Kalahari ecosystem. The natural history of wild dogs in the Kalahari has never been studied in detail. I will focus on two aspects of the species' ecology: diet and spatial use. Diet analysis will consist of scat collection and recording presence and proportion of prey species. At least two individuals in each pack will be immobilized and receive a GPS or standard radio telemetry collar to record the pack's movements. Used by the BWDRP since 2001, new GPS collar technology allows highly detailed and systematic locational data of territory use to be collected for the first time. The BWDRP is one of five studies in Africa shown to cause no increased risk of mortality through handling (Ginsberg et al 1995).

What are the conditions that wild dogs prey on livestock? Constructing a spatial distribution of depredation will suggest potential conditions under which wild dogs prey on domestic stock. Initial data collection will concentrate on building a geographic database of livestock areas including type (cattle, sheep, goat), breed, and quantity of livestock, husbandry techniques (free-range, herded), and proximity to wilderness areas. Some large-scale ranching areas exist as discrete blocks that will facilitate geographical information system (GIS) analysis and will provide a clear representation of a natural experimental system where different ranch variables influence wild dog behavior. Wild prey levels represent an important source of variation across the ranching landscape. Likely due to differences in range quality and intensity of human hunting, wild ungulate levels are not homogenously distributed across ranching blocks (Swarner, pers. obs.). Using wildlife transects, I will measure three species expected to be wild dogs' predominant prey: steinbok, bush duiker, and greater kudu.

The spatial and temporal variations of conflict are important clues to understanding wild dog behavior on ranchland. If stock loss is widespread and sporadic, multiple wild dogs packs likely contribute equally to depredation events throughout the year. Conversely, localized stock loss suggests involvement of a smaller number of packs, associated with the area in which the loss occurred. In addition, for three months of the year, wild dog movement is closely restricted to a reproductive burrow site suggesting that livestock loss may be seasonally intense if packs den on or near ranching land. Because wild dogs are involved in conflict on reserve edges (Linnel et al. 2001, Woodroffe and Ginsberg 1998), predation is expected to occur more frequently on ranches closer to the boundaries of protected or otherwise wilderness areas.

I predict livestock depredation to be highest during the wild dog denning season (May to August) and in livestock areas bordering or located within wilderness areas and containing low levels of wild prey. Much of this analysis can be completed with existing data as one district office of Botswana's Problem Animal Control (PAC) program contains available records for over 100 cases of loss attributed to wild dogs since 1998.

How much economic loss is occurring relative to land use? I will estimate economic loss due to wild dogs to provide important perspective on other causes of stock loss including starvation, disease, and accident. Economic loss can be quantified by a minimal count of confirmed depredation events as well as more generally through sociological surveys. Because livestock depredation and carnivores are often emotional and sensitive issues, survey work among ranchers will be conducted only after I have developed a relationship within the ranching community with the goal of obtaining more reliable answers.

Incorporating a common technique from epidemiology (Doll and Hill 1950), I plan to investigate differences in stock depredation by case-control analysis. Every time a depredation event is recorded, I will collect information on the habitat where the attack occurred, the age and breed of the stock victim, and husbandry technique. For comparison, each depredation "case" will be matched by collecting identical information from a minimum of three neighboring "control" ranches that were not attacked. Case-control data will be analysed using conditional logistic regression.

Can wild dog behavior and/or livestock husbandry be modified to mitigate stock loss? Although managers have attempted a wide variety of tactics to reduce carnivore predation on livestock without lethal control, most past work has been frustrated by behavioral habituation (Cluff and Murray 1995), translocation failure (Bangs et al. 1998), or limitations of intensive management (Fritts et al. 2003). Yet, a diverse set of repellents and incentive programs are currently being tested around the world and may provide local or more hopefully, broadly-applicable solutions (Mishra et al. 2003, Shivik et al. 2003, Treves and Karanth 2003). Still, given the low success of aversive conditioning in other canids (Cluff and Murray 1995), attempts to change wild dog behavior are likely to be less productive than changing human behavior. Encouraging human practices that reduces livestock loss to predators need not incorporate novel or expensive techniques (such as many of those listed in Table). In Kenya, Ogada et al. (2003) found that traditional, low-tech husbandry practices such as the use of nighttime corrals and the presence of guard dogs and humans can reduce livestock depredations in some contexts. The most productive strategy in Botswana will likely be the identification and encouragement of human behavior that 'works' for both ranching and conservation as well as cautious testing of techniques that discourage depredation behavior.

Does predator removal reduce livestock depredation? Predator removal is a common response to human-carnivore conflict, both historically and currently (Boitani 1995, Treves and Karanth 2003b). Removal includes translocation, but more often refers to humans directly killing predators by poison, firearms, traps, and other methods. Despite a recent surge of public opposition against lethal control in management, some workers in conservation biology have suggested that predator control is essential to remove 'problem' animals and garner local support (Mech 1995). However, not all predator removal strategies are equally effective in reducing depredation. Sheep depredation by coyotes in northern California suggest that breeding coyotes are more likely to be stock-killers, seasonal removal of breeding coyotes on territories with young sheep reduces depredations, non-selective removal does not reduce future livestock loss, and recurring depredation following removal probably correlates with surrounding predator density and territory replacement time (Sacks et al. 1999, Blejwas et al. 2002). Likewise, Till and Knowlton (1983) found that selective removal of the offspring of depredating coyotes reduced livestock loss almost as much as removing the adults. This evidence suggests that removal is most successful when selective with a thorough understanding of context. For many African carnivores, despite widespread lethal control, we know very little about the selectivity of removal or if it reduces future livestock loss. Throughout assessment of livestock depredation in Botswana, I plan to monitor how livestock loss changes through time following removal of wild dogs and other large carnivores.

Conclusion. Wild dogs are a species of special conservation concern. They are few in number and those that remain exist in fragments, susceptible to the two-fold threat of human contact: increased risk of disease and persecution. Humans persecute wild dogs primarily because the species represents a threat to livestock, even if the actual amount of loss is low. If such carnivore species are to persist, conservation biologists must work to assess depredation and understand when it occurs to mitigate those causes in innovative ways. Finally, wildlife managers and public stakeholders must be convinced that wild dogs can be tolerated within the landscape. This will be a challenge in many African contexts, but the alternative is a continuance of wild dog recent history: extinction.

The immediate results of research on livestock depredation and potential methods to limit ranging behavior will provide much needed information on wild dog conflict with humans. However, my research also has very practical benefits to local ranchers and I plan to collaborate closely with relevant government agencies to maximize the long-term use of my results. Survey work and spatial analysis of depredation events can accommodate data analysis on three additional large carnivores associated with livestock depredation in central Botswana: lions, leopards, and cheetah. Table 3 suggests the expected depredation patterns for four large African carnivores according to their ecology and our knowledge of livestock depredation in other systems.

Carnivore conflict with people is a widespread and historical cause of carnivore mortality and, in the last century, severe population decline. Particular attention has been given to the North American and Eurasian wolf in this regard. A rich literature exists on the relationship of the wolf to human communities (Lopez 1978, Carbyn et al. 1995, Fritts et al. 2003) and the situation of the wolf parallels that of African wild dogs in some important ways (Fuller 1995). Wolves and wild dogs both endured extermination schemes in the early 20th century, although at least in the U.S., wolf eradication differed in being substantially more systematic and widespread. The presence of wolves in areas of domestic stock has produced a prolific literature focusing on wolf depredation (Lopez 1978), and work has recently intensified following continental U.S. reintroductions that received widespread national attention (Mech 1995, Bangs et al. 1998, Treves et al. 2002). In Europe, where wolves are more commonly found in urban or otherwise degraded habitats compared to North America, depredation on livestock can be a frequent and even dependent habit of wolves (Fritts et al. 2003). In most areas, wolves tend to prey more on domestic stock when wild prey populations are low and depredations can be reduced after native prey is restored or rebounds. Existing work on wolf stock depredation has much potential to inform and direct comparable work on African wild dogs.

I have focused comparison with wolves, in part because the two canid species share many similarities (Fuller 1995), but it is important to note the potential application of methods and results to other carnivores in North America (mountain lions, coyotes, bear) and globally (tigers, Asian dholes, jaguar, African lions, leopards, hyenas, and cheetah) where depredation on domestic stock has been implicated as a cause of conflict and a research priority. Work to mitigate human-predator conflict on wild dogs has widespread application to resolve human-predator conflict in Botswana, in the U.S., and on a global scale.

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Threats	Why is it threatening?	Where is threat most relevant?
Habitat fragmentation	Produces isolated populations and low numbers that increase the probability of extinction due to human-induced mortality, environmental stochasticity and genetic processes	Throughout Africa
Human persecution	Increases mortality directly; Areas with higher human densities correlate positively with wild dog extinction probability	Particularly on reserve edges and outside protected areas, but also within small protected areas that have high edge effects
Disease	Increases mortality directly; Outbreaks can lead to local extinctions even within large protected areas	Throughout Africa, but particularly where disease in domestic dogs is poorly managed
Predation by larger carnivore species	Increases mortality directly; Inside protected areas, lion and hyena predation are significant sources of mortality; Wild dogs avoid lions spatially	Where wild dog ranges overlap with high densities of lions and hyenas
Accidental snaring	Increases mortality directly	Where subsistence snare use is common
Road casualties	Increases mortality directly	Where roads intersect wild dog ranges and high speed traffic is common
Competition with other carnivores	May increase mortality indirectly; Hyenas and lions steal wild dog kills frequently in some ecosystems and may reduce overall wild dog feeding success	Where wild ungulate abundance is limited, kills are easily detected, and/or other carnivore species coexist at high densities

Table 1. Threats that contribute to African wild dog extinction risk. See Creel and Creel 1996, Woodroffe and Ginsberg 1999.

Method	Description	Advantages	Drawbacks	Potential for an African application
Removal				
Translocation	Predator is captured and typically moved to a remote location away from the source of conflict	Livestock producers are often satisfied that individual has been moved; Does not kill animal directly	Translocated individual may die anyway in territorial conflicts with conspecifics; Cost is usually high; Individual may return	Cost would usually be prohibitive
Non-selective lethal control	Indiscriminate killing of predators	Potentially reduces loss and satisfies livestock producer	May be opposed by sectors of the public; results in widespread mortality of predators irregardless of depredation history; may not reduce future conflict	Currently practiced
Selective lethal control	Killing individuals that are thought to be responsible for livestock depredation	Selective against carnivores that attack livestock; Potentially reduces loss and satisfies livestock producer	May be opposed by sectors of the public; requires additional time and effort to identify, track, and kill guilty predator	Good potential if local motivation exists
Livestock protection collars	A toxicant-filled rubber container attached to a collar and placed on the neck of livestock	Highly selective; Kills attacking predator with minimal human intervention	Predator must attack livestock with collar to be effective; Collars banned by some governments due to use of poison	Very little
Non-removal				
Toxic aversion	Noxious substances that irritate attacking predator	Highly selective; Acts only on attacking predators	Have been shown to be ineffective and unreliable	None
Herding	Presence of one or more humans that remain with group of livestock	Traditional practice; Can be incorporated with defense against livestock theft	Requires human presence; traditional herder demographic may be involved in other activities (e.g. school, city life)	Currently practiced although in some areas is replaced

Livestock refuges	Providing bomas, corrals, or some other kind of refuge for livestock to aggregate in at night or during calving	Traditional physical deterrence; Can be built out of local materials	Must build and maintain refuge; Concentrated livestock may result in surplus killing occasionally	Currently practiced, some *boma* designs may be superior
Synchronized birthing	Breeding livestock to birth in synchrony so that vulnerable calves exist less av. time per year	Mimics natural defense of wild ungulates; Minimizes overall annual loss	Requires additional effort in ranch management; May require cooperation of surrounding ranchers	Currently practiced in some areas, readily applicable in others
Livestock breeds with anti-predator behavior	Using breeds of livestock that still retain vestiges of anti-predator behavior (e.g. flight, circling around calves, aggressive)	Natural defense; Requires no additional effort by rancher	Breeds may be too aggressive and difficult to ranch in other aspects	Indigenous breeds likely exhibit some form of anti-predator defense
Fladry	Flagging hung from ropes strung a short distance off the ground	Cheap; Effectively separates or directs some carnivores	Habituation may be rapid; Untested on many carnivores in wild	Unknown
Guard animals	The presence of domestic dogs, llamas, and donkeys have been used to deter predator attacks (mainly in Europe)	Multiple guard species to choose from; some subsist on same food as livestock	Many guard animals are untested regarding their effectiveness; guard dogs may attract predators or kill livestock themselves	Guard dogs used in some contexts; Use of other species is unlikely but untested
Fences	Barrier that restricts movement; Can be electrified	Permanent deterrence; Clear delineation between people and wildlife areas; Effective	Requires effort to build and maintain; Are often permeable; Can be detrimental to wildlife movements	Currently practiced

Table 2. Methods used that have attempted to prevent or reduce livestock depredation. See reviews in Cluff and Murray 1995, Shivik et al. 2003.

Species	Social structure (Hunting style if different)	Territory size (km^2) [a]	Livestock at highest risk	Expected depredation pattern by:			
				Gender [b]	Season [a,c]	Carnivore abundance [d]	Ranging behavior [e]
African wild dog	Social	450-700	Sheep, goats, <2 yr old cattle	Both	May-July	Infrequent	Sporadic but potentially localized during breeding
Leopard	Solitary	14.0-32.8	Sheep, goats, <2 yr old cattle	Male-biased	?	Frequent	Continuous and localized
Cheetah	Solitary	?	Sheep, goats	Male-biased	?	Moderate	?
Lion	Social (Social and solitary)	?	Sheep, goats, cattle, camels	Both or male-biased	?	Moderate	?
Spotted hyena	Social (Social and solitary)	?	Sheep, goats, <2 yr old cattle	Both or female-biased	?	Frequent	Continuous and possibly localized

Table 3. Expected depredation pattern by five large African carnivores. Depredation behavior is expected to vary by species' ecology including sexual dimorphism, breeding season, abundance, and ranging behavior. [a] Data sources: African wild dog, Woodroffe et al. 1997; Leopard, Mizutani and Jewell 1997; Cheetah ?; Lion ? ?; Sp. Hyena, ?. [b] If larger territory and body size and 'bolder' behavior correlate positively with depredation, particularly in solitary species. [c] If carnivore breeding season correlates positively with depredation. [d] If abundance directly relate to depredation rate. [e] If wide ranging behavior results in sporadich depredation events, species with smaller territories or concentrated foraging behavior are expected to exhibit more continuous and/or localized depredation.