Acta Agric. Scand., Sect. A, Animal Sci. 2000: 50, 279–290
Printed in Ireland. All rights reserved

ACTA AGRICULTURÆ
SCANDINAVICA
ISSN 0906–4702

Review of Methods to Reduce Livestock Depredation: I. Guardian Animals

Smith, M. E., Linnell, J. D. C., Odden, J. and Swenson, J. E. (Nord-Trøndelag College, Department of Resource Sciences, Box 145, 7702 Steinkjer, Norway, Norwegian Institute for Nature Research, Tungesletta 2, 7485 Trondheim, Norway and Hedmark College, 2480 Koppang, Norway). Review of methods to reduce livestock depredation: I. Guardian animals. Accepted January 22, 2000. Acta Agric. Scand., Sect. A, Animal Sci. 50: 279–290, 2000. © 2000 Taylor & Francis.

The use of domestic animals to protect livestock was reviewed through visits to actual users, discussions with experts and a thorough literature search. Costs and benefits were analysed in terms of reduced livestock losses. The most common guardian animals are dogs, which have been shown to reduce predation (documented mostly for coyote) by 11–100%. Livestock guardian dogs have also been used effectively against bear, wolf and cheetah. Donkeys are also used as guardian animals, and their effectiveness lies in their natural herding behaviour and aggression, especially against canids. The effectiveness of donkeys varies considerably dependent upon the predator species and the temperament of the individual donkey. Llamas are also used as a guardian animal, with approximately the same characteristics as the donkeys, and will defend themselves against most predators. The use of guardian animals appears to be an effective tool for reducing livestock depredation and should be evaluated in areas with high predation losses against the cost of changing production systems.

Martin E. Smith[1,*], John D. C. Linnell[2], John Odden[3] and Jon E. Swenson[2,†]

[1]Nord-Trøndelag College, Department of Resource Sciences, Box 145, 7702 Steinkjer, Norway, [2]Norwegian Institute for Nature Research, Tungesletta 2, 7485 Trondheim, Norway and [3]Hedmark College, 2480 Koppang, Norway

Key words: cattle bonding, guardian donkeys, guardian llamas, livestock guarding dogs, predation.

Introduction

The idea of using one species of domesticated animal to provide predator protection for another is an ancient concept. Archaeological excavations have revealed the remains of domestic dogs and sheep together (although not necessarily employed in a guarding capacity) from as far back as 3685 BC (Olsen, 1985, cited in Coppinger & Coppinger, 1993).

By far the most prevalent and most successful guard animals in use today are various breeds of livestock guarding dogs (LGD) (*Canis familiaris*), although donkeys (*Equus asinus*) and llamas (*Lama glama*) are also used under certain circumstances. In addition to these, certain cattle breeds, goats, and even ostriches (*Struthio camelus*) and baboons (*Papio hamadryas*) are used as some kind of a guard for 'their' flock of animals (Franklin & Powell, 1993; Marker-Kraus et al., 1996).

The type of guard animal employed will depend upon the type of livestock being defended, the predator species, the intensity of predation, the grazing habitat of the livestock and the management system employed by the producer. For example, in North America, llamas may provide adequate protection of sheep from individual coyotes (*Canis latrans*) and dogs, but may themselves fall prey to predators such as grizzly bears (*Ursus arctos*), wolves (*C. lupus*), mountain lions (*Felis concolor*) and dog packs.

Guard animals have been used with varying success to guard various forms of livestock including horses, cattle, sheep, goats, camels, llamas, ostriches, emu, turkeys, chickens, ducks and pheasants. Guardian

*Corresponding author.
† Current address: Norwegian Agricultural University, Institute for Biology and Nature Conservation, P.B. 5014, 1432 Ås, Norway.

animals have been used against such predators as coyote, feral and domestic dogs, bobcat (*Lynx rufus*), lynx (*Felis lynx*), dingo (*Canis familiaris* dingo), foxes (*Vulpes* spp.), mountain lion, wolf, bear, jackals (*Canis mesomelas*, *C. adustus*), spotted hyaena (*Crocuta crocuta*), striped hyaena (*Hyaena hyaena*), wild dog (*Lycaon pictus*), caracal (*Caracal caracal*), baboon, lion (*Panthera leo*), leopard (P. pardus) and cheetah (*Acinonyx jubatus*) (Kruuk, 1980; Green & Woodruff, 1989a; Green et al., 1993; Floyd, 1995; Coppinger & Coppinger, 1996b; Andelt, 1996; Marker-Kraus et al., 1996).

The majority of the scientific literature concerns the use of LGD, but there is an increasing emphasis on experiments using alternative animals. The following review focuses on protection of sheep from predation, but applies to the protection of other livestock species as well. Some of the positive and negative effects of this type of management will be identified and a simplified cost–benefit analysis presented.

Methods

The authors contacted many of the known experts in the field, seeking their advice on the most important literature, as well as copies of the more obscure material. As much of the original literature as possible was reviewed and an extensive reference section has been included. In addition, the authors visited areas of the western USA where predation losses are high and these types of antipredation technique are commonly used. The information obtained from the literature, from the scientific experts, and directly from farmers and ranchers employing these techniques was incorporated into this review, presenting both the positive and negative aspects for each of these guardian animals. A simplified cost–benefit summary is then presented, based solely on the savings as a result of reduced livestock losses against the expenses incurred by the farmers.

Results and discussion

Livestock guarding dogs

The actual techniques of using dogs as guardians are thoroughly described in a collection of papers written in *c.* 150 BC on Roman farm management (Anon., 1913, cited in Coppinger & Coppinger, 1993). In a few European countries (e.g. Italy, France, Portugal), LGD have apparently been in use for thousands of years. In other areas, where predators were virtually extirpated, the tradition of using LGD has been forgotten. Today, the use of LGD is most common in the USA, with thousands of dogs in use, distributed over the entire country. With the re-establishment of carnivores, some European countries must now import new bloodlines of LGD back from the USA and relearn the techniques of using them.

It is important to distinguish between the LGD and the herding dog, thought to have become more prevalent as large predators became less of a threat. The first evidence of herding dogs originated from Iceland and the Faeroe Islands around 1200–1220 and they were then further developed in Great Britain (after wolves were extirpated), where they were used to help farmers drive their sheep (Laurans, 1975). In France and Italy (where wolves persist), however, sheep are still kept together with a herder and a mastiff or wolfhound for protection (Thomas, 1983, cited in Coppinger & Coppinger, 1993). The herding dogs are behaviourally much nearer actual predators and threaten the sheep into going where they are directed with clear predatory mannerisms. Guardian dogs are long removed from the predator end of the canid behaviour spectrum. LGD are 'permanent adolescents', genetically adapted to retain some adolescent behavioural traits as adults, thus encouraging behaviour that can be described as trustworthy (will not harm the flock), attentive (stays with the flock) and protective (barks and defends the flock) (Coppinger et al., 1983; Coppinger & Coppinger, 1996b).

Most of the available scientific literature arises from two separate research groups, both begun in 1976 in the USA. The first scientific evaluation of LGD began at the Denver Wildlife Research Center (then under the US Fish and Wildlife Service) testing Komondor dogs as guards against coyotes (Linhart et al., 1979; McGrew & Blakesley, 1982). This work was continued under the US Department of Agriculture, Agricultural Research Service, at the US Sheep Experiment Station (USSES), Dubois, Idaho. The USSES work focused on observations of controlled coyote–dog confrontations. Subsequently, dogs were distributed to active sheep ranches, with follow-up surveys about the dogs' effectiveness (Green & Woodruff, 1980, 1983; Green et al., 1984a).

The second group independently began research in the same year, establishing the Livestock Dog Project at Hampshire College in Amherst, Massachusetts. This group investigated existing LGD operations in Europe and imported several breeds back into the USA for a breeding programme (Coppinger & Coppinger, 1980b, 1982). These dogs and their offspring were also distributed to farmers and evaluated annually. An active research programme centred on understanding the basic behavioural aspects of LGD: what defines a 'good' livestock guardian dog, how these behaviours are acquired and maintained, and the evolutionary significance related to other breeds

and wild canids (Coppinger et al., 1987; Coppinger & Coppinger, 1993; Coppinger & Schneider, 1995).

Breeds

Most of the breeds in use as LGD today are European or Asian breeds bred specifically for useful characteristics in guarding against predators (Coppinger & Coppinger, 1980a,b; Green & Woodruff, 1980). Nearly all breeds are similar in appearance: large, 35–45 kg and 65 cm or more at the shoulder (Andelt, 1996), and most have white coats (several are brown and/or black) in various lengths. One exception to the Eurasian breeds is the small mongrel dog traditionally used by the Navajo Indian Tribes of Arizona and still effectively used today (Black, 1981; Black & Green, 1984; Coppinger et al., 1985; Black, 1987).

Techniques

The use of LGD now is substantially different to the techniques employed 2000 years ago, in response to different livestock management requirements. Earlier, the LGD was used with small flocks and a herder, whereas today dogs guard flocks of 1000 or more sheep and work more or less independent of the herder. To be effective today LGD are therefore required to be more strongly bonded to sheep than to people. There are several publications from both research groups and Agricultural Extension Services from various states that fully explain the process of selecting, rearing and using LGD (McGrew & Andelt, 1985, 1986; Lorenz & Coppinger, 1986; Lorenz, 1989a; Green & Woodruff, 1990a; Andelt, 1995). Rearing techniques vary, depending on the personality of the individual dog (and owner) and the sheep husbandry system in use.

In general, the most important factor is early bonding to the flock, accomplished by placing 6–8-week-old pups with the sheep. One rancher visited by the authors kept a ewe with the bitch and her pups from 2–3 weeks of age (Hansmire/Cambell Ranch, Cisco, UT, 1996). Pups older than 8–10 weeks have passed the primary socialization stage (Coppinger & Coppinger, 1993), where bonding is most successful, although some individuals have been bonded as late as 12 weeks or more (but with less positive results). As the pups grow they are sometimes moved into increasingly larger pens, but are always kept with sheep until ready to join the flock. The only 'training' during this period is to reinforce 'staying with the sheep' (correcting the dog when it leaves them) and correcting negative play behaviours that eventually could result in injuries to sheep (play-chasing, ear and wool pulling, etc.). From about 6–8 months old the dogs can start being left alone on the open range with continued observation to ensure that no undesirable behaviours develop. A rancher in Eastern Washington would place pups as young as 2–3 months old (with their mother) out with the sheep on the open range. They would be moved with the shepherd's camp but were nevertheless exposed to their working environment from a very early age (Martinez Livestock, Moxee, WA, 1996). Throughout the entire process it is critical to remember that the dog is a working dog and not a pet. Human contact is important, but not to the extent that the dog becomes more bonded to humans than to sheep. For more specific details the reader is referred to the previous references.

Effectiveness

The reported percentage of LGD that are successful guardians varies from 66 to 90% (Coppinger et al., 1988; Green et al., 1994) and the reduction in predation varies from 11 to 100% (Linhart et al., 1979; Green & Woodruff, 1980; Green et al., 1984a; McGrew & Blakesley, 1982; Pfeifer & Goos, 1982; Black & Green, 1984; Andelt, 1987, 1996; Coppinger et al., 1988; Green & Woodruff, 1988; Lorenz, 1989b). What appears to be particularly enlightening is a number of surveys conducted over 15 years to register the opinions of active sheep producers regarding LGD in their operations (Green et al., 1984b; Lorenz et al., 1986; Coppinger et al., 1988; Green, 1989; Green & Woodruff, 1990b). For example, Green & Woodruff (1988) found in a survey of 400 producers using 763 dogs that 82% of the dogs were 'an economic asset' and 9% were a 'break-even' investment. In Colorado, Andelt (1992) found that sheep producers with LGD lost fewer sheep to all causes than producers without LGD. Because LGD are often used in conjunction with other predator control methods, it is difficult to attribute such reductions to LGD alone; however, many ranchers have been able to reduce other control measures after incorporating LGD into their management (Andelt, 1992).

In the USA, the majority of predation on livestock is from coyotes, and the previous results are naturally most related to reductions in coyote predation. The original breeds of LGD were developed in Europe to combat predation by brown bear and wolves. No scientific publications are found documenting their success (Coppinger & Coppinger, 1996a); however, popular accounts have been well documented (Coppinger & Coppinger, 1982, 1993, 1996a).

Bears. In recent years there has been an increased effort to document LGD interactions with these large carnivores and some experimental trials have been conducted expressly for that purpose. Green &

Woodruff (1989a) document 20 encounters between LGD and bears (17 black bears and three grizzly bears), with 75% of these resulting in the bears being chased off or shot before predation occurred. Grizzly bears appeared more difficult to dissuade than black bears, but a small sample ($n = 3$) makes generalization impossible.

In 1992, another demonstration of LGD was conducted in the Absorka Mountains, a wilderness area in Montana just north of Yellowstone National Park (Green et al., 1993). In this area of high bear densities and limited control possibilities due to the protected status of the grizzly bear, two LGD were placed with the flock to test their effect. Over 7 weeks the herder documented 10 bear–dog encounters (night occurrences, so bear species was not determined), resulting in four sheep being killed. On five occasions the herder helped and on three occasions the dogs acted alone to frighten the bear away without depredation. On the two occasions that losses occurred, both dogs were occupied with separate bears. No coyote predation occurred in spite of numerous sightings. Another article expanding the information above with data from 1990–1993 (including before dogs were used) documented 40 bear–sheep encounters. Of these encounters, 29 sheep were killed in the 2 years before employing dogs and seven sheep were killed in the 2 years after employing dogs. The dogs were observed successfully to frighten away the bears before the latter killed sheep on at least 12 occasions while working alone, and on six occasions together with the herder (Wick, 1995). Wick (1995) points out that important additive factors to the LGD effectiveness were the attentiveness of the herder, disposing of carcasses (burned) and regularly moving the herd. Woodruff (1996, pers. comm.) also believes that this combination of herder and dogs working together as a team was essential for their effectiveness.

Several confrontations have been filmed between three Great Pyrenees and brown bears in the Pasvik region of northern Norway. Over a period of several days these dogs repeatedly harassed a female with yearlings and a large male (four or five separate confrontations) until they eventually left the area (NRK-TV News, Oslo, Svanhovd Miljøsenter, 9925 Svanvik, Norway).

In another study conducted in the Snåsa area of central Norway, three radio-collared dogs were released within 100 m of a radio-collared brown bear (Hansen, 1996). The dogs neared the bear about 10 min after the last dog was released, and they subsequently chased it for 25 min over a distance of *c*. 1 km. The dogs appeared to work independently of each other, with one dog consistently near the bear and another dog returning regularly to check on the people. The bear was radio-tracked and appeared to be on his way back to the original site after about 1 h, indicating little long-term effect with just one dog encounter (Hansen & Bakken, 1999). Hansen and her colleagues continued investigating the use of LGD under various working regimes (Hansen & Smith, 1999) and found that with the dogs available to them (i.e. dogs that were not strongly bonded to sheep), patrolling an area with a dog and handler was probably best.

Studies of conflicts between bears and sheep on the Targhee National Forest, USA, showed that improved herder techniques were most responsible for reducing all losses, including bear depredation (Jorgensen, 1983). She went on to say that portable corrals, sheep-protecting dogs and aversion methods could provide additional help in reducing sheep losses.

Preliminary results from a 3-year project in Norway that combined herding (up to 500 sheep) with newly imported LGD (Poland, Owczarek Phodalanski; and Italy, Masstino Abruzzese) show a reduction in predator loss to one ewe over the 3 years versus 15–20% in the control (Krogstad et al., 1999, 1998, in prep.). They also documented numerous encounters with brown bears in which the dogs were successful in chasing the bear away (Krogstad et al., 1999, in prep.).

Felids. Predation by large cats on livestock has been a substantial problem in many places around the world, and the main reason for many cat species' threatened or endangered status (Sawarkar, 1986; Rabinowitz, 1986; Cunningham et al., 1995; Nowell & Jackson, 1996). In recent years, protection and reintroduction programmes have led to increasing conflicts outside protected areas in largely livestock-dominated agricultural zones (Nowell & Jackson, 1996). Little has been documented specifically about LGD encounters with the various felid predators. However, there are many anecdotal reports from LGD users in the USA that report success against mountain lions (and assumedly bobcats as well). Mountain lions only represent 7.7% and bobcats 2.5% of the total predation on sheep and goats in the USA (USDA, 1995), but can cause a severe impact locally. Because so few ranches are exposed to mountain lion predation, it is difficult to ascertain statistically the effects of LGD on the overall rates.

In Kenya, Kruuk (1980) found that dogs were a common form of protection around some villages at night, but they seldom used dogs out with the herds while grazing. They were not typical guardian dog breeds, but rather 'pie dogs' or pariah dogs typical of Africa and Asia (thought to be similar to Rhodesian Ridgebacks). Kruuk further showed reduced levels of

predation among members of the Gabra tribe that used many dogs. The specific effect of dogs on individual predator species was not determined, but the villages have most depredation problems with lion, spotted hyaena, cheetah, wild dogs and black-backed jackals.

In Namibia, the Cheetah Conservation Fund has imported LGD for use by local livestock owners as a non-lethal alternative for reducing cheetah predation (Marker-Kraus & Kraus, 1993; Marker-Kraus et al., 1996). They are trying to re-establish dwindling populations of cheetah in non-protected areas, traditionally used for livestock grazing. Although the project is in its infancy, they are reporting success, with reduced predation and observations of the dogs repelling attacks by caracal, jackal and baboon (Cheetah Conservation Fund, 1995).

Wolves. The use of LGD against predation by wolves has a long tradition in Europe and Asia (Coppinger & Coppinger, 1996b). Coppinger & Coppinger (1996a) reviewed the available European literature and noted that there were few technical publications available, but that popular accounts showed that wolf and bear were still the most common adversaries for LGD. Wolves currently present a minor, although locally severe, depredation problem in North America (Fritts et al., 1992). However, owing to the protected status of wolves and efforts for reintroduction, their significance on livestock predation will undoubtedly increase (Fritts, 1993). Coppinger (1987, cited in Coppinger et al., 1988) first evaluated the effectiveness of LGD for protecting cattle from wolves in Minnesota. They documented several interactions without any injuries sustained by either the dogs or wolves. Rather, the encounters resembled normal dog–dog (wolf–wolf) interactions to ascertain dominance status. They concluded that LGD maintained their protective roles against wolves not by direct aggression but rather by disrupting the normal predatory sequence of the wolves. Wolves would either avoid the LGD territories or be distracted into other behaviours (greeting, ritualized contests to determine status, play, etc.), thus increasing the effort needed to make a kill (Coppinger & Coppinger, 1996a).

In addition, they found that LGD effectively prevented feeding by wolves and black bears at carrion feeding stations (Coppinger et al., 1987, cited in Andelt, 1996; Coppinger & Coppinger, 1996a). Coppinger (1992) discussed the similarities between LGD and wolves, and proposed a mechanism through which LGD could be successful at guarding livestock against a behavioural conspecific. In general, wolves avoid the LGD initially, but over a period of weeks will come closer and closer until near contact is made.

The Coppinger group also observed wolf–LGD interactions under controlled conditions within a large fenced enclosure at Wolf Park, Indiana (Coppinger & Coppinger, 1996a). Results of this work affirmed the conspecific nature of the wolf–dog relationship, but also showed the dominance of wolves over LGD in direct confrontations. Why wolves avoid LGD in the field remains an unanswered question.

With respect to reintroduction, Coppinger & Coppinger (1996a) recommend that LGD be established with livestock in possible conflict zones long before the wolves' arrival, giving the LGD time to establish their territories. It should also be pointed out that wolves have killed dogs, including Anatolian Shepherds in Minnesota and Montana (Fritts & Paul, 1989; Woodruff, pers. comm., 1996). Bangs et al. (1998) also identified LGD mortalities attributed to grey wolf (*c*. 1 per year in each of the three recovery areas) during the last 5 years of wolf restoration (with over 300 wolves) in the western USA The LGD losses are compensated from a private fund using the same procedures as other livestock losses.

Wolverines. Only one study reports a direct confrontation with wolverines (Hansen et al., 1998). Hansen and her colleagues have studied the use of LGD in a patrolling fashion under the control of a person. The wolverine appeared 20 m ahead of the dog and controller in an open forest terrain. The dog immediately ran barking at the predator and chased it away. The dog returned 15–20 min later. Preliminary results of this study using LGD in a patrolling mode have shown a reduction in predation to 2–4% in areas where wolverine losses have traditionally been *c*. 15% (Hansen et al., 1997, 1998). This general pattern of chasing the intruder for a few minutes and then returning was repeated in several encounters with foxes as well. However, should wolverines choose to attack the LGD, they would probably succeed in killing the dogs. This is true with all of the large predators, and that it is not the LGD fighting ability that protects the flock, but rather their interference with the normal predatory routine.

Costs

The initial costs for LGD range from $240 to $1000 depending on the age and breed (Green et al., 1984a; Lorenz, 1989b; Andelt, 1996). First-year costs of shipping, feed, veterinary expenses, travel, damages caused by the dogs, etc., average between $700 and $900. Subsequent mean annual expenses range from $250 to $290 (Green et al., 1984a; Andelt, 1992). Time investment in supervision, training and feeding of LGD averaged 9 and 10 h month^{-1} for 37 and 21

ranchers, respectively (Green et al., 1984a; Andelt, 1992).

Eleven of 44 ranchers (25%) in the Green et al. (1984a) survey reported that dogs had injured or killed livestock. Fourteen of 135 dogs (10%) killed or injured at least one sheep or goat in their lifetime. Of these, nine were isolated incidents in dogs less than 2 years old that later became good LGD. However, five (4%) of the dogs persisted in livestock killing and were culled (Green et al., 1984a).

Benefits

Green & Woodruff (1989b) report that 82% of livestock producers using dogs in the USA and Canada thought that LGD were an economic asset. Ninety-nine per cent of the 360 producers using pasture-grazing systems and 38 of 39 producers grazing open ranges recommended dogs. Results were varied between LGD working the open ranges and those in fenced pasture systems, although both were generally good (Table 1).

Green & Woodruff (1985) found that 73% of producers reported that LGD resulted in annual savings averaging $180–14487 [calculated by dividing the difference of (dog expenses) – (value of sheep saved) by the number of years for which a dog was in use]. Andelt (1992) reported that 11 Colorado producers calculated that LGD saved sheep worth $3216 annually. In Oregon, Lorenz (1989b) found that small flock owners (mean = 105 sheep, range 30–400) saved $501 per dog and large producers (mean = 644 sheep, range 500–2600) saved $615 per dog.

With any tool there will be some situations where its use will be limited. This is equally true of LGD. Green & Woodruff (1985) effectively summarized both the positive and negative impacts of incorporating LGD into a livestock management plan. Their results are quoted below.

The reported benefits were:

- Reduction in predation
- Reduced labour (i.e. no longer confining or corralling sheep nightly, sheep graze in a tighter flock thus are easier to monitor)
- If night confinement is discontinued, pastures can be utilized more efficiently and condition of sheep may be improved
- Increased utilization of areas where predators had made grazing prohibitive prior to use of dogs
- Increase in grazing area may provide opportunity to increase the size of the flock
- Improved potential for profit
- Dog alerts owner to disturbance (predators) near the flock
- Increased self-reliance in managing predator problems
- Protection for family members and farm property
- Peace of mind.

Although most of the dogs that are reared to protect sheep are ultimately successful, there are potential problems during the adolescent period of the dog as well as problems that may develop with an experienced dog. Many of the problems are considered to be minor by most producers, but others are serious. The following potential problems were identified:

- Dog harasses sheep (usually a play behaviour), resulting in injury or death
- Dog does not guard sheep
- Dog is overly aggressive to people
- Dog harasses other animals (livestock or wildlife)
- Expenditure of labour to train and supervise the dog
- Dog destroys property (chewing objects, digging)
- Dog is subject to illness, injury or premature death
- Dog roams beyond farm boundaries causing problems with neighbours
- Dogs require a financial investment with no guarantee of securing an effective guardian
- Dog interferes when sheep are moved or interferes with herd dog
- The incorporation of this system causes reduced growth in the animals not previously herded.

There have been other studies showing mixed or negative results of LGD (Lorenz et al., 1986; Timm & Schmidt, 1989; Krogstad et al., 1999, in prep), but the above list adequately details the problems encountered. The end result is that in most cases LGD

Table 1. Evaluation of effectiveness of livestock guarding dogs by 399 respondents during a 1986 survey of livestock producers from the US and Canada

	Performance rating of dogs			
Grazing system	Very effective	Not effective	Effective	Totals
Pastures	475 (71%)	144 (21%)	52 (8%)	671
Open range	60 (66%)	17 (19%)	14 (15%)	91

After Green & Woodruff (1989b).

Table 2. Percentages of 60 Texas sheep and goat producers reporting various effectiveness ratings of guard donkeys against common mammalian predators

Predator	Excellent	Good	Fair	Poor	Failure	Unknown
Coyote	3	17	20	25	17	18
Dog	2	18	22	13	15	30
Fox	0	10	13	5	8	69
Bobcat	0	5	5	5	13	72

After Walton & Feild (1989).

appear to be a cost-effective tool to help in reducing the problem of predators.

For those readers wishing more detailed information on Livestock guardian dogs the following three publications are highly recommended: Green & Woodruff (1990a), Coppinger & Coppinger (1993) and Andelt (1996).

Guard donkeys

Donkeys are descendants of the wild ass (*Equus hemionus*) and are small, sturdy animals (0.8–1.5 m at the shoulder) found throughout the world (Varshney & Gupta, 1994). They are generally thought to be divided into two species, the African or true wild ass (*E. asinous*) and the Asiatic wild ass or half ass (*E. heminous*). Donkeys were first domesticated around 2650 BC in the Nile Valley and have a physiological tolerance for extremes, both nutritional and climatic (Varshney & Gupta, 1994). Historically, donkeys have been used as draught animals, static power, cart animals, pack animals, riding animals, and for meat, milk, fuel and fertilizer (dung) (Varshney & Gupta, 1994). A recent addition to this list is their use as guard animals.

Apparently, using donkeys as guardian animals relies upon their herding instincts and their innate dislike and aggressiveness towards canids. To date, there has been no controlled testing of the effectiveness of donkeys against various predators, although some studies are in progress. There are numerous popular accounts of their use, but only three scientific publications that survey their use as livestock guardians.

The most comprehensive publication (Walton & Feild, 1989) estimated that 1000–1800 of the 11000 active sheep and goat ranchers in Texas used donkeys as guard animals (based on a survey sent to 500 producers). Green (1989) bases an estimate of donkey use on the percentage of donkeys adopted in the US Government's 'Adopt A Burro' Program. Since 1972, 13229 donkeys have been adopted as pets, breeding stock or guardians by people throughout the USA. Data from one area (South Dakota) indicate that in 1988, 62% of 50 adopted donkeys were intended for use as guard animals. This figure rose steadily, with 73% of 113 donkeys in 1989 and 79% of 114 donkeys in 1990. These figures indicate an increasing tendency for using donkeys as guardians.

Low purchase price (mean \$144, range \$65–250), minimal maintenance costs (mean \$66, range \$0–300), long life expectancy (10–20 years), no labour invested in training, no special feeding requirements and compatibility with other lethal predator control techniques (specifically, M-44s and 1080 collars) are the reasons for the increasing interest in donkeys (Green, 1989; Walton & Feild, 1989). However, their range of usefulness appears to be more limited than dogs.

The effectiveness of donkeys as guardians is highly variable, depending upon the type of predator and the temperament of the individual donkey (Green, 1989; Walton & Feild, 1989). Poor husbandry practices and unrealistic expectations are cited by Walton & Feild (1989) as accounting equally for the failures of donkeys. In a survey of 17 known donkey users 59% of the donkeys were rated as good or fair. In a second survey conducted by Walton & Feild (1989) of 500 sheep and goat producers, 60 of the 275 respondents replied with ratings for their donkey's effectiveness (Table 2).

The reactions of donkeys to larger predators such as puma and bear are not well documented, but second-hand reports tell of donkeys 'running in terror' at their approach (Green, 1989). However, Marker-Kraus et al. (1996) report that many farmers in Namibia use donkeys successfully to ward off cheetah attacks. They relate the story of another Namibian farmer who observed a mule (*E. asinus* × *E. caballus*) trample a leopard to death.

In summary, it appears that under relatively restricted conditions donkeys can be used to help against some predator problems. The results of donkeys as guardians are considerably more inconsistent than livestock guardian dogs, and field conditions appear to be significantly more restrictive. The following list from Walton & Feild (1989) outlines the husbandry conditions necessary for the maximum effectiveness of donkeys as guardian animals.

- Guard donkeys should be selected from medium to large size stock. Do not use extremely small or miniature donkeys.
- Do not acquire a donkey which cannot be culled or sold if it fails to perform properly.
- Use jennies (females) and geldings. Do not use jacks (intact males) as guard animals.
- Test a new donkey's guarding response by challenging the donkey with a dog in a corral or small pasture.
- Use only one donkey or jenny with foal, per pasture.
- Isolate guard donkeys from horses, mules and other donkeys.
- To increase probability of bonding, donkeys should be raised from birth or placed at weaning with sheep and goats.
- Raise guard donkeys away from dogs. Avoid or limit the use of herding dogs around donkeys.
- Monitor the use of guard donkeys at lambing or kidding, as some donkeys may be aggressive to newborns or overly possessive. Remove donkeys temporarily if necessary.
- Use donkeys in small ($< c.$ 240 ha) open pastures with not more than 200 head of sheep or goats for best results. Large pastures, rough terrain, dense brush, too large a herd, and sheep or goats that are scattered all lessen the effectiveness of guard donkeys.
- Do not allow donkeys access to feed containing Rumensin, urea or other products intended only for ruminants.

Because of the ease of management with guard donkeys, their use will probably continue to expand. With additional research, better techniques and selection criteria for guarding donkeys (sex, breed line, etc.) will be developed, increasing their utility in the future.

Guard llamas

The most complete work on guard llamas is an Iowa State University Cooperative Extension Service publication entitled 'Guard Llamas' (Franklin & Powell, 1993). There are several other popular publications available through local llama groups, such as 'Llamas for guarding livestock' (International Llama Association, 1996).

Llamas are members of the South American camelid family composed of four groups: the llama and alpaca are domesticated and the guanaco and vicuña are wild. Llamas, guanacos, alpacas and their hybrids are all used as guard animals but are all referred to as llamas (Franklin & Powell, 1993). However, Trondsen & Hansen (1995) report that alpaca producers in Israel find llamas to be more territorial and defensive than alpacas and use llamas to protect flocks of alpacas. Field studies in South America have reported observations of the wild species actively pursuing foxes but fleeing from pumas. Apparently, these species are very territorial and even the domestic varieties will aggressively defend their pasture (Franklin & Powell, 1993).

Franklin & Powell (1993) conducted telephone interviews with 145 sheep producers in the USA using 204 guard llamas. Their study revealed that 70% used gelded males costing $700–800, with an average of one llama per 284 sheep (range 4–2150). Average pasture size was 100–120 ha (range 2–3239 ha) and producers had been using llamas for an average of 3 years (range < 1–12 years). The average llama was 2 years old when first introduced to the sheep flock, with 50% adjusting to the sheep within a few hours and 80% adjusting within a week. Producers reported that llamas could become closely bonded to sheep and show intense attachment to young lambs (Franklin & Powell, 1993).

Average annual predation losses from 1972–1991 were reported by 114 producers to be 11% (mean = 26 sheep and lambs). This figure dropped to 7% (mean = eight sheep and lambs) after introducing llamas. Eighty-eight per cent of the producers responded as satisfied (18%) or very satisfied (70%) with their guard llamas, citing predator control and ease of maintenance as the top benefits. An average gross annual saving of $1253 (range $0–20000) was reported among 87 producers (Franklin & Powell, 1993).

Problems encountered by the producers surveyed by Franklin & Powell (1989) included attempts to breed ewes, aggressive behaviour (assumedly towards the sheep), overprotectiveness and interference of sheep with feeding llamas.

Whereas the Franklin and Powell survey indicates relatively good success with guard llamas, there continues to be much scepticism. The present authors received many comments from llama breeders relaying numerous accounts of llamas falling prey, not only to large predators, but also to single coyotes and dogs (C. Rogers, M. Jarvis & L. Keller, pers. comm., 1996). Many of these breeders now use LDG to protect their llama flocks. It appears that more concrete studies should be conducted to identify more clearly and perhaps reinforce the guarding traits found in some llamas. Such research is underway at the USSES, and through Dr Fred Knowlton at the USDA National Wildlife Research Center.

Cattle

Some promising research has been performed on bonding sheep to cattle to decrease the risk of preda-

tion (Hulet et al., 1987, 1989; Anderson et al., 1988, 1994). This technique reduces predation, but also enables better use of the grazing lands (Glimp, 1988), minimizes stress at weaning of sheep (Hulet, 1988) and controls the spatial distribution of sheep without fencing (Anderson et al., 1994).

The process of bonding sheep to cattle was accomplished by placing 45–90-day-old lambs together with cattle in a small, 139 m^2 pen for 60 consecutive days (Anderson et al., 1987). After bonding, the average distance between sheep and cattle was reduced and in the presence of an emulated predator (trained border collie), the sheep responded by positioning themselves among the cattle and away from the dog (Anderson et al., 1988). Cattle aggression (kicking and charging) was observed only when the dog approached the cattle, indicating that the protection afforded sheep is a passive byproduct of their close association with these potentially threatening animals (Anderson et al., 1988).

In 1986, Hulet et al. (1987) placed nine cattle-bonded lambs together with seven heifers at the Jornada Experimental Range in south-west New Mexico, USA. For comparison, they placed unbonded lambs in adjacent pastures and rotated the control group with the test (bonded) group from pasture to pasture. During three trials no bonded lambs were lost during 163 days of testing, compared with 13 of 23 unbonded lambs or ewes lost over 63 days of testing (confirmed or strongly suspected to be coyote kills).

This group has also bonded goats to sheep and cattle, successfully reducing predation among those goats bonded to sheep and cattle. Five-month-old goats, kept together with cattle for 60 days, were placed in two groups for an additional 14 days of bonding. Group 1 was with two heifers, group 2 was with eight cattle-bonded sheep and a heifer, and group 3 was a control group of unbonded goats, sheep and heifers. Comparisons among the three groups showed that only group 2 resulted in reduced predation. This supports previous observations of success with sheep bonded to cattle, but indicates the necessity for goats to bond with sheep that are already bonded to cattle. Through this method, they will remain near the cattle and obtain the same passive protection as sheep (Hulet et al., 1989).

Problems associated with this technique are primarily the additional costs and labour involved during the bonding period. Anderson et al. (1994) estimate that the cost for pen confinement of 42 lambs for 55 days was \$0.51 day^{-1} per lamb. These costs can be offset by reduced predation loss, reduced fence expenses and reduced time spent searching for sheep (Anderson et al., 1994). At this time, it is not possible to give adequate estimates of these savings. The effectiveness of this technique in areas impacted by large, cattle-killing predators is unknown, but likely to be greatly reduced and highly variable.

Further research is needed to discover the most effective herd composition for both sheep and cattle (breed, sex, age, numbers, etc.) as well as exploring less expensive bonding techniques.

Other species

The following animals have also been briefly mentioned in the literature as guard animals, although their use is probably quite limited: goats, baboons, zebras and stallion horses in Namibia (Marker-Kraus et al., 1996), ostriches in South Africa (Franklin & Powell, 1993; Jennings, pers. comm., 1996) and kangaroos (Franklin & Powell, 1993).

Conclusion

The use of LGD can be a viable management tool in areas currently reintroducing, or encouraging the increase of, predator populations. Dogs have repeatedly shown that they are effective in helping to reduce predation under a variety of conditions, including with free-ranging sheep grazing in forested habitats similar to those found in Norway (Hansen et al., 1996). However, traditional livestock management techniques may have to be modified and will require additional research to identify how LGD can best be incorporated into current systems. Clearly, for LGD to be effective there must be a flock of sheep for them to protect. The current studies by Krogstad et al. (1998, 1999, in prep.) will help to illustrate how this management tool can be incorporated into today's free-ranging systems and at what cost. For example, initial results from Krogstad and his colleagues showed *c.* 5–30% less weight gain for sheep that were herded compared with those that were free ranging. This reduced meat production appears to be lessened with each year in which the sheep were herded. Their final report (Krogstad et al., in prep.) will include a detailed cost analysis of shifting over to a herding with guardian dogs management system based on the actual figures of herding over 500 sheep.

The use of donkeys and llamas is less promising because most livestock are grazed on the open range and these guardian animals need enclosed pastures to work best. In addition European depredations are usually from large predators (bears, wolves, wolverines and lynx) and these guardian animals are likely to become prey themselves. Bonding

sheep to cattle also appears to have potential. Here again, additional research is needed to document the best combination of breeds and numbers of bonded animals, and to document the effectiveness of bonding under various conditions. Prior to greater acceptance and use of these management tools some displacement of predator activity on to neighbouring, unprotected sheep may be experienced, but the extent of this needs additional documentation.

Acknowledgements

This review was part of a larger project to review methods for reducing carnivore–livestock conflicts in Norway, financed by the Norwegian Directorate for Nature Management and the Ministry of Agriculture. The Nord-Trøndelag County Governor's Office, Environmental Department, provided additional funding for the USA tour. Special thanks are extended to Inger Hansen for inviting us along on her trip to the USA and to Roger Woodruff for planning and guiding us through an extremely informative tour. Thanks also to the personnel of the National Wildlife Research Center, Fort Collins, CO, for an informative tour of their facility. Editorial comments are gratefully acknowledged from Roger Woodruff, Lorna and Ray Coppinger, Inger Hansen and William Andelt.

References

Andelt, W. F. 1987. Coyote predation. In: Novak, M., Baker, J. A., Obbard, M. E. & Malloch, B. (eds) Wild Furbearer Management and Conservation in North America. Ontario Ministry of Nature Reserves and Ontario Trappers Association, Toronto, pp. 128–140.

Andelt, W. F. 1992. Effectiveness of livestock guarding dogs for reducing predation on domestic sheep. Wildl. Soc. Bull. 20, 55–62.

Andelt, W. F. 1995. Livestock guarding dogs, llamas, and donkeys for reducing livestock losses to predators. Colorado State Univ. Coop. Ext. 1/95 Pub. No. 1.218, 4 pp.

Andelt, W. F. 1996. Carnivores. In: Krausman, P. R. (ed.) Rangeland Wildlife. Society for Range Management, Denver, CO, pp. 133–155.

Anderson, D. M., Hulet, C. V., Smith, J. N., Shupe, W. L. & Murray, L. W. 1987. Bonding of young sheep to heifers. Appl. Anim. Behav. Sci. 19, 31–40.

Anderson, D. M., Hulet, C. V., Shupe, W. L., Smith, J. N. & Murray, L. W. 1988. Response of bonded and non-bonded sheep to the approach of a trained border collie. Appl. Anim. Behav. Sci. 21, 251–257.

Anderson, D. M., Havstad, K. M., Shupe, W. L., Libeau, R., Smith, L. N. & Murray, L. W. 1994. Benefits and costs in controlling sheep bonded to cattle without wire fencing. Small Ruminant Res. 14, 1–8.

Bangs, E. E., Fritts, S. H., Fontaine, J. A., Smith, D. W., Murphy, K. M., Mack, C. M. & Niemeyer, C. C. 1998. Status of gray wolf restoration in Montana, Idaho & Wyoming. Wildl. Soc. Bull. 26, 785–798.

Black, H. L. 1981. Navajo sheep and goat guarding dogs: a new world solution to the coyote problem. Rangelands 3, 235–238.

Black, H. L. 1987. Dogs for coyote control: a behavioral perspective. In: Green, J. S. (ed.) Protecting Livestock From Coyotes. A Synopsis of Research. Agric. Res. Serv. Nat. Tech. Info. Serv., PB 88 133590/AS, pp. 69–75.

Black, H. L. & Green, J. S. 1984. Navajo use of mixed-breed dogs for management of predators. J. Range Manage. 38, 11–15.

Cheetah Conservation Fund. 1995. Livestock guarding dog program update. Cheetah Conserv. Fund Newslett., 5, 4, Windhoek, Namibia.

Coppinger, R. 1992. Can dogs protect livestock against wolves in North America? Livestock Guarding Dog Ass. DogLog 3(2), 2–4.

Coppinger, R. & Coppinger, L. 1980a. Livestock guarding dogs. Country J. 7 (4), 68–74.

Coppinger, L. & Coppinger, R. 1980b. So firm a friendship. Nat. Hist. 89 (3), 12–26.

Coppinger, R. & Coppinger, L. 1982. Dogs in sheep's clothing guard flocks. Smithsonian 13 (1), 64–73.

Coppinger, L. & Coppinger, R. 1993. Dogs for herding and guarding livestock. In Grandin, T. (ed.) Livestock Handling and Transport. CAB International, Wallingford, UK, pp. 179–196.

Coppinger, R. & Coppinger, L. 1996a. Interactions between livestock guarding dogs and wolves. In: Carbyn, L. N., Fritts, S. H. & Seipm D. R. (eds) Ecology and Conservation of Wolves in a Changing World. Canadian Circumpolar Institute, Univ. of Alberta, Edmonton, pp. 523–526.

Coppinger, R. & Coppinger, L. 1996b. Biologic bases of behavior of domestic dog breeds. Readings in Companion Anim. Behav. 9–18.

Coppinger, R. & Schneider, R. 1995. Evolution of working dogs. In: Serpell, J. (ed.) The Domestic Dog. Cambridge University Press, Cambridge, pp. 22–47.

Coppinger, R., Lorenz, J., Glendinning, J. & Pinardi, P. 1983. Attentiveness of guarding dogs for reducing predation on domestic sheep. J. Range Manage. 36, 275–279.

Coppinger, R., Smith, C. K. & Miller, L. 1985. Observations on why mongrels may make effective livestock protecting dogs. J. Range Manage. 38, 560–561.

Coppinger, R., Glendinning, J., Torop, E., Matthay, C., Sutherland, M. & Smith, C. 1987. Degree of behavioral neoteny differentiates canid polymorphs. Ethology 75, 89–108.

Coppinger, R., Coppinger, L., Langeloh, G., Gettler, L. & Lorenz, J. 1988. A decade of use of livestock guarding dogs. Proc. of the 13th Vert. Pest Conf. 13, 209–214.

Cunningham, S. C., Haynes, L. A., Gustavson, C. & Haywood, D. D. 1995. Evaluation of the interaction between mountain lions and cattle in the Aravaipa-Klondyke area southeast Arizona. Final Rep. AZ Game and Fish Dep., Res. Branch Tech. Rep. 17, Phoenix, AZ, 64 pp.

Floyd, J. 1995. Training the Anatolian Shepherd dog for poultry guarding. Coban Chatter, 5(3) reprinted: http://www.terminus.com/ ~ halpin/page4.htm

Franklin, W. L. & Powell, K. J. 1993. Guard llamas. Iowa State Univ., Univ. Ext., PM-1527, 12 pp.

Fritts, S. H. 1993. Controlling wolves in the greater Yellowstone area. In: Cook, R. S. (ed.), Ecol. Issues on Reintroducing Wolves into Yellowstone Nat. Park. USDI Nat. Park Serv., Sci. Mono. NPS/NRYELL/NRSM-93/22, pp. 173–233.

Fritts, S. H. & Paul, W. S. 1989. Interactions of wolves and dogs in Minnesota. Wildl. Soc. Bull. 17, 121–123.

Fritts, S. H., Paul, W. J., Mech, L. D. & Scott, D. P. 1992. Trends and management of wolf–livestock conflicts in Minnesota. US Fish and Wildl. Serv., Resource Pub. 181, 27 pp.

Glimp, H. A. 1988. Multi-species grazing and marketing. Rangelands 10, 275–278.

Green, J. S. 1989. Donkeys for predation control. Proc. of the 4th East. Wildl. Damage Ctl. Conf. 4, 83–86.
Green, J. S. & Woodruff, R. A. 1980. Is predator control going to the dogs? Rangelands 2, 187–189.
Green, J. S. & Woodruff, R. A. 1983. The use of three breeds of dog to protect sheep from predators. Appl. Anim. Ethol. 11, 141–161.
Green, J. S. & Woodruff, R. A. 1985. Summary of the livestock guarding dog research at the U.S. Sheep Exp. Sta. Sheep Prod. January/February, 12–14.
Green, J. S. & Woodruff, R. A. 1988. Breed comparisons and characteristics of use of livestock guarding dogs. J. Range Manage. 41, 249–251.
Green, J. S. & Woodruff, R. A. 1989a. Livestock guarding dogs reduce depredation by bears. In: Bear–People Conflicts – Proc. of a Symp. on Manage. Strategies. NWT Dept of Renew. Res., Yellowknife, pp. 49–53.
Green, J. S. & Woodruff, R. A. 1989b. Producers rate their guard dogs. Nat. Wool Grower, April 6–7 and 30.
Green, J. S. & Woodruff, R. A. 1990a. Livestock guarding dogs: protecting sheep from predators. US Dept. of Agric. Agric. Info. Bull. No. 588, 29 pp.
Green, J. S. & Woodruff, R. A. 1990b. ADC guarding dog program update: a focus on managing dogs. Proc. of the 14th Vert. Pest Conf. 14, 233–236.
Green, J. S., Woodruff, R. A. & Tueller, T. T. 1984a. Livestock-guarding dogs for predator control: costs, benefits, and practicality. Wildl. Soc. Bull. 12, 44–50.
Green, J. S., Woodruff, R. A. & Harman, R. 1984b. Livestock guarding dogs and predator control: a solution or just another tool? Rangelands 6, 73–76.
Green, J. S., Woodruff, R. A. & Wick, P. J. 1993. Bears, ostriches and specialized grazing: putting guarding dogs to work. Proc. of the 11th Great Plains Widl. Damage Ctl. Workshop 11, 105–108.
Green, J. S., Woodruff, R. A. & Andelt, W. F. 1994. Do livestock guarding dogs lose their effectiveness over time? Proc. of the 16th Vert. Pest Conf. 16, 41–44.
Hansen, I. 1996. Bruk av vokterhund som vern mot rovdyr i beiteområder for sau. Sluttrapport. Planteforsk, Norsk institutt for planteforskning, Tjøtta fagsenter, 8860 Tjøtta.
Hansen, I. & Bakken, M. 1999. Livestock-guarding dogs in Norway: Part I. Interactions. J. Range Manage. 52, 2–6.
Hansen, I. & Smith, M. E. 1999. Livestock-guarding dogs in Norway: Part II. Different working regimes. J. Range Manage. 52, 312–316.
Hansen, I., Smith, M. E. & Trondsen, Ø. 1996. Studietur til USA. Bruk av vokterhund og andre forebyggende tiltak mot rovdyrskader på bufe. Erfaringer fra USA. Rapport, Planteforsk, Norsk institutt for planteforskning, Tjøtta fagsenter, 8860 Tjøtta, 40 pp.
Hansen, I., Staaland, T. & Ringsø, A. 1997. Bruk av vokterhund som vern mot rovdyr i beiteområder for sau. Erfaringer fra feltforsøk i Hattfjelldal. Rapport, Planteforsk, Norsk institutt for planteforskning, Tjøtta fagsenter, 8860 Tjøtta, 21 pp.
Hansen, I., Staaland, T. & Ringsø, A. 1998. Vokterhund på patrulje i kombinasjon med tilsyn. Evaluering of metoden. Rapport 11/98. Planteforsk, Norsk institutt for planteforskning, Tjøtta fagsenter, 8860 Tjøtta, 26 pp.
Hulet, C. V. 1988. A review: understanding sheep behavior, a key to more efficient and profitable lamb and wool production. SID Res. J. 5, 26–32.
Hulet, C. V, Anderson, D. M., Smith, J. N. & Shupe, W. L. 1987. Bonding of sheep to cattle as an effective technique for predation control. Appl. Anim. Behav. Sci. 19, 19–25.
Hulet, C. V, Anderson, D. M., Smith, J. N., Shupe, W. L., Taylor, C. A. & Murray, L. W. 1989. Bonding of goats to sheep and cattle for protection from predators. Appl. Anim. Behav. Sci. 22, 261–267.
International Llama Association 1996. Llamas for guarding livestock. Internet page address: http://www.webcom.com/~degraham/Assn/GuardILA.html
Jorgensen, C. J. 1983. Bear–sheep interactions. Targhee Nat. For. Intl. Conf. for Bear Res. and Manage. 5, 191–200.
Krogstad, S., Anderson, R., Christiansen, F., Smith, M. E. & Trondsen, Ø. 1998. Forebyggende tiltak mot rovdyrskader på sau. Gjeting og bruk av voktehund i Lierne. Årsrapport fra fase I – 1997. NINA oppdragsmelding 539, 1–21.
Krogstad, S., Christiansen, F., Smith, M. E., Moen, R., Westerdahl, K., Tillung, R. H. & Moen, A. 1999. Forebyggende tiltak mot rovdyrskader på sau. Gjeting og bruk av voktehund i Lierne. Årsrapport fra fase II – 1998. NINA oppdragsmelding 583, 1–56.
Kruuk, H. 1980. The effects of large carnivores on livestock and animal husbandry in Marsabit District, Kenya. UN Environ. Prog. – Man and Biosphere. Integrated Project in Arid Lands, Tech. Rep. No. E-4. UNEP – MAB, Nairobi, 53 pp.
Laurans, R. 1975. Sheep guarding and conducting dogs (English translation LGDA DogLog 1992). Ethnozootechnie 12, 15–18.
Linhart, S. B., Sterner, R. T., Carrigan, T. C. & Henne, D. R. 1979. Komondor guard dogs reduce sheep losses to coyotes: a preliminary evaluation. J. Range Manage. 32, 238–241.
Lorenz, J. R. 1989a. Introducing livestock-guarding dogs. OR State Univ. Ext. Serv., Circ. No. 1224. 4 pp.
Lorenz, J. R. 1989b. Reducing predator losses with livestock guarding dogs. In: Lorenz, J. R. and Erskine, K. (eds) Coloured Sheep and Wool: Exploring Their Beauty and Function. Proc. of the World Cong. on Coloured Sheep, Ashland, OR, pp. 202–205.
Lorenz, J. R & Coppinger, L. 1986. Raising and training a livestock-guarding dog. OR State Univ. Ext. Serv., Circ. No. 1238/April 1986, 8 pp.
Lorenz, J. R., Coppinger, R. P. & Sutherland, M. R. 1986. Causes and economic effects of mortality in livestock guarding dogs. J. Range Manage. 39, 293–295.
Marker-Kraus, L. and Kraus, D. 1993. The history of cheetahs in Namibia. Swara, September–October, 8–12.
Marker-Kraus, L., Kraus, D., Barnett, D. & Hurlbut, S. 1996. Cheetah survival on Namibian farmlands. Cheetah Conserv. Fund. Windhoek, Namibia, 85 pp.
McGrew, J. C. & Andelt, W. F. 1985. Livestock guardian dogs: a new method for reducing livestock losses. Coop. Ext. Serv., Kansas State Univ., Manhattan, 8 pp.
McGrew, J. C. & Andelt, W. F. 1986. Livestock guardian dogs: a method for reducing livestock losses. CO State Univ. Coop. Ext., Fort Collins, 4 pp.
McGrew, J. C. & Blakesley, C. S. 1982. How Komondor dogs reduce sheep losses to coyotes. J. Range Manage. 35, 693–696.
Nowell, K. & Jackson, P. 1996. Wild cats: status survey and conservation action plan. IUCN, Gland, Switzerland, 382 pp.
Pfeifer, W. K. & Goos, M. W. 1982. Guard dogs and gas exploders as coyote depredation control tools in ND. Proc. of the 10th Vert. Pest Conf. 10, 55–61.
Rabinowitz, A. R. 1986. Jaguar predation on domestic livestock in Belize. Wildl. Soc. Bull. 14, 170–174.
Sawarkar, V. B. 1986. Animal damage: predation on domestic livestock by large carnivores. Indian For. 172, 858–866.
Timm, R. M. & Schmidt, R. H. 1989. Management problems encountered with livestock guard dogs on the Univ. of Calif., Hopland Field Sta. Proc. of the 9th Great Plains Widl. Damage Ctl. Workshop 9, 54–58.
Trondsen, Ø. & Hansen, I. 1995. Bruk av stor pyreneehund som værn mot rovdyr. Studietur til Isreal. Unpub. Rep. Sankerens Kennel, Unset, Norway, 14 pp.

USDA 1995. Sheep and goat predator loss. Nat. Agric. Stat. Serv. Rep. Apr., 16 pp.

Varshney, J. P. & Gupta, A. K. 1994. The donkey and its potential – a review. Int. J. Anim. Sci. 9, 157–167.

Walton, M. T. & Feild, C. A. 1989. Use of donkeys to guard sheep and goats in Texas. Proc. of the 4th East. Widl. Damage Ctl. Conf. 4, 87–94.

Wick, P. J. 1995. Minimizing bear–sheep conflicts through herding techniques. Non-referred Proc. of the 9th Intl. Conf. for Bear Res. and Manage., France, pp. 367–373.