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Introduction

Predation by coyotes (*Canis latrans*), domestic dogs, mountain lions (*Felis concolor*), black bears (*Ursus americanus*), red foxes (*Vulpes vulpes*), golden eagles (*Aquila chrysaetos*), and bobcats (*Felis rufus*) has been a major problem faced by domestic sheep, goat (NASS, 2000), and cattle (NASS, 2001) producers. Predators were reported to kill 273,000 sheep and lambs (NASS, 2000) and 147,000 cattle and calves (NASS, 2001) in the United States, and 61,000 goats in Arizona, New Mexico, and Texas (NASS, 2000) during either 1999 or 2000. Several methods, including the use of livestock guarding dogs, llamas, and donkeys, have been used to reduce these mortalities (Andelt, 1996, 2001). In this paper, I summarize use and effectiveness of livestock guarding animals for reducing predation on domestic sheep and goats. Recent reviews of livestock guarding animals are provided by Smith et al. (2000) and Rigg (2001).

Livestock guarding dogs

Livestock guarding dogs have been used in the United States since the early 1970s to protect sheep and goats from predators. Most guarding dog breeds have been selectively developed in Europe and Asia to protect livestock from bears (*Ursus* spp.) and wolves (*Canis lupus*). The most common breeds used in the United States are Great Pyrenees, Akbash, and Komondor (Green and Woodruff, 1988; Andelt and Hopper, 2000), whereas the Anatolian Shepherd, Maremma, Shar Planinetz, and mixed breed dogs are used less frequently. Most guarding dogs weigh 75-100 pounds and are ≥ 25 inches at the shoulders. Successful guarding dogs are trustworthy (will not harm sheep), attentive to sheep, and aggressive toward predators (Coppinger et al., 1983). These traits are "instinctive;" they develop in most dogs with proper handling and minor training.

Guarding dog pups cost an average of $240 in Kansas (Andelt 1985), $176 in North Dakota (Bergman et al., 1998), and $331 and $458 (depending on breed) in the western United States (Green et al., 1984). Annual maintenance fees (food, veterinary care, miscellaneous costs) averaged $235-$250 (Green et al., 1984; Andelt, 1985).

About 28% of sheep producers in the United States used guarding dogs to protect sheep during 1999 (NASS, 2000). Andelt and Hopper (2000) reported that the percentage of sheep with guarding dogs in fenced pastures and on open range in Colorado increased from 7% in 1986 to 65% in 1993. They also indicated that primarily producers with large flocks of sheep have incorporated guarding dogs.

Sheep producers in Colorado who did not use livestock guarding dogs lost 5.9 and 2.1 times greater proportions of lambs to predators than producers who had dogs in 1986 and 1993 (Andelt and Hopper, 2000). Predation on ewes and lambs decreased more from 1986 to 1993 for producers who obtained dogs between these years compared to producers who did not have dogs. A total of 125 producers in Colorado estimated that their 392 dogs reduced predation losses by $891,440 in 1993. Thirty-six producers in North Dakota reported guarding dogs reduced predation on sheep by 93% (Pfeifer and Goos, 1982).

Producers in Colorado indicated that guarding dogs greater than 9 months of age saved more time in sheep management than the amount of time spent feeding and working with each dog (Andelt, 1992). Overall, guarding dogs are a cost effective means of reducing predation (Green et al., 1984; Andelt and Hopper, 2000).

Livestock guarding dogs have been successful in reducing predation by coyotes on domestic sheep (Pfeifer and Goos, 1982; Coppinger et al. 1983; Andelt and Hopper, 2000). Producers with guarding dogs, compared to producers without guarding dogs, also sustained fewer ewe and lamb mortalities to black bears and mountain lions (Andelt and Hopper, 2000). Guarding dogs repelled black bears and grizzly bears (**Ursus arctos**) during most encounters (Green and Woodruff, 1989; Green et al., 1993; Hansen and Bakken, 1999). Guard dogs, at least in North America, may not be effective against wolves. There are documented cases of wolves killing dogs, and some reports of dogs pair-bonding with wolves and assisting in livestock depredation (M. Collinge, USDA/APHIS Wildlife Services; personal communication).

Disadvantages of guarding dogs include some dogs not staying with or harassing sheep, some dogs, especially Komondors, being overly aggressive toward people (Green and Woodruff, 1988; Andelt, 1992), and the dogs can be subject to injury and premature death. Many of the disadvantages are relatively uncommon. Most producers surveyed feel strongly that the advantages of their dogs far outweigh the disadvantages.

Green and Woodruff (1988) reported that the rate of success in protecting livestock from predators did not

vary among several breeds of guarding dogs, nor was the rate of success different among males and females or intact and neutered dogs. Dogs that were reared with livestock from ≤ 2 months old had a significantly higher rate of success than dogs that were > 2 months old when placed with livestock. Ratings of effectiveness of guarding dogs by producers using one breed of dog in Colorado did not differ among breeds, but producers who used multiple breeds rated Akbash more effective than Great Pyrenees and Komondors (Andelt, 1999).

Guarding dog pups should be raised, preferably with a few head of bum lambs in a small pen in a barn or isolated area away from the flock, starting at 6 to 8 weeks of age when they develop a strong bond with sheep (Andelt, 1995). A pup should be treated like a working dog in the operation from the beginning. Pups should not be allowed to play with children or herd dogs or hang around the house. As a pup gets older, it should be introduced to equipment, machinery, other livestock (horses, cattle, chickens), and herding dog(s) so later it will not guard the sheep from them. A producer should spend some time with a pup so that it is not afraid of them and can be captured later on. A pup should not be rewarded when it wanders away from the sheep.

A pup should be raised, preferably with lambs that will be incorporated into the main flock. Once one group of sheep accepts the dog, other sheep unaccustomed to guarding dogs tend to accept it more quickly. High-quality dog food should be provided in a self feeder near the sheep at all times. A barrier should be placed around the feeder to exclude the sheep, or the dog may remain near the feeder, guarding it from the sheep.

When a dog matures and begins to work, it will stay with sheep willingly, and its barking and scent marking with urine will increase. These behaviors notify predators that a dog is present and help deter them from approaching the sheep. Coyotes and other predators usually remain in the area but are prevented from killing sheep.

Most producers who have <200 sheep, or graze sheep in <200-acre fields, usually use one or two guarding dogs. Producers who graze 1,000 ewes and their lambs on open range often use two to five dogs. The number of dogs used usually depends on the extent of predation, dispersion of sheep, and amount of brushy cover on the range.

Llamas

Llamas have been used to deter predation primarily by coyotes, red foxes, and dogs since the early 1980s. About 13% of sheep producers in the United States used llamas to protect sheep from predators during 1999 (NASS, 2000). Llamas are naturally aggressive toward coyotes and dogs. Typical responses of llamas to coyotes and dogs are being alert, alarm calling, walking to or running toward the predator, chasing, kicking, or pawing the predator, herding the sheep, or positioning themselves between the sheep and predator.

Franklin and Powell (1993) surveyed 145 producers who used llamas, primarily in Montana, Wyoming, Colorado, California, and Oregon. Most producers used one gelded male with 250 to 300 sheep in 250- to 300-acre pastures. Nearly all llamas were not raised with sheep and were not trained to guard sheep. One llama was more effective than multiple llamas for deterring predation; the effectiveness of gelded males, intact males, and females was similar. However, producers reported more problems with intact (25% of 61 intact males) than gelded males (5% of 135 gelded males) attempting to breed ewes. Sheep that were introduced to llamas in corrals initially sustained lower mortalities than those introduced in pastures. The success of llamas was not related to age when the llama was introduced, age of llama (after 1 or 2 years old) when guarding, if lambs were present or absent when the llama was introduced, or between open and covered (forested, shrub lands, gullies, ravines, etc.) habitat. However, Cavalcanti and Knowlton (1998) reported that weight, alertness, and leadership of llamas were correlated with aggressiveness toward dogs and should be considered when selecting potential guardians.

Franklin and Powell (1993) reported that gelded male llamas cost $700 to $800 and intact males were about $100 cheaper, whereas Bergman et al. (1998) reported that llamas cost an average of $450 in North Dakota. Most producers reported that daily care for llamas was the same as for sheep and that no special feeds were provided. Average annual expense was $90 for feed (not including pasture) and veterinary costs were about $15.

Franklin and Powell (1993) reported that 21% of ewes and lambs were killed annually before acquiring a llama and 7% afterwards. Meadows and Knowlton (2000) reported that producers with llamas lost significantly fewer sheep to predators than producers without llamas during the first year of use, but mortalities did not differ during the second year in Utah.

Donkeys

About 9% of sheep producers in the United States used donkeys to protect sheep from predators during 1999 (NASS, 2000). Donkeys apparently have an inherent dislike for dogs and other canids. They will bray, bear their teeth, run and chase, and attempt to bite and kick an intruder (Green, 1989).

Donkeys apparently are most effective in small open pastures or where sheep graze together. Green (1989) and Walton and Feild (1989) recommended using only one jenny or gelded jack per pasture because two or more donkeys often stay together instead of being with the sheep. Intact jacks generally are too aggressive around sheep. Donkeys generally should be allowed 4 to 6 weeks for bonding with sheep before they are used to deter predators. Donkeys should be removed during lambing because they might trample lambs or disrupt the ewe-lamb bond. Green (1990) recommended challenging a donkey with a dog to test its response to canids; donkeys that are not aggressive should not be used.

The average purchase price per donkey was $144 in Texas (Walton and Feild,1989) and $236 in North Dakota (Bergman et al., 1998). Walton and Feild (1989) reported that average annual upkeep per donkey was $66.

Bonding sheep and goats to cattle

Bonding young sheep to cattle (Anderson et al., 1987; Hulet et al., 1987) and goats to sheep which have been bonded to cattle (Hulet et al., 1989) has reduced predation by coyotes. This technique has not been readily adopted by sheep producers, possibly

because of the additional labor, expense, and practicality involved with bonding sheep and goats to cattle, or perhaps ineffectiveness; cattle, and calves in particular, have been killed by predators (NASS, 2001).

Relative effectiveness of guarding animals

Benefits of using guarding animals include a decrease or elimination of predation, reduced labor to confine sheep and goats at night, more efficient use of pastures for grazing, reduced reliance on other predator control techniques, and a greater peace of mind. A comparison of surveys where producers reported the average annual value of sheep saved per guarding animal suggests guarding dogs, compared to llamas, saved more sheep from predators (Table 1). Guarding dogs and llamas have been rated as more effective than donkeys for deterring predation (Table 1; NAHMS 1996a,b [cited by Connolly and Wagner, 1998]).

Advantages of donkeys and llamas over guarding dogs include less prone to accidental death, longer-lived, do not require special feeds, stay in the same pasture as sheep, apparently do not need to be raised with sheep, more compatible with other depredation control techniques, such as traps, snares, M-44s (sodium cyanide injectors), and livestock protection collars, and donkeys are cheaper than guarding dogs. Alternately, guarding dogs deter predators in fenced pastures and on open range, whereas llamas and donkeys appear most effective in fenced pastures < 300 acres. Guarding dogs are effective in deterring bear and mountain lion predation (Green and Woodruff, 1989; Andelt and Hopper, 2000), whereas some donkeys (Green, 1989) and possibly llamas are afraid of bears and mountain lions. Although one early report indicated that guarding dogs could protect cattle from wolf predation (Coppinger et al., 1988), and were fairly effective in keeping wolves and black bears from carrion feeding sites in Minnesota (Coppinger et al., 1987), wolves have killed some domestic dogs (Fritts and Paul, 1989; Bangs et al., 1998), and dogs may serve to attract wolves to livestock under some circumstances.

Several methods, including livestock confinement, disposal of livestock carcasses, herders, fencing, frightening

Table 1. Average annual value of sheep saved from predation by each livestock guarding animal and ratings of effectiveness of guarding animals as reported in various studies.

Factor	Guarding dogs	Llamas	Donkeys
Value of sheep saved	$3,836[a]	$1,253[b]	
	$2,506[c], $3,733[c]		
Ratings of effectiveness			
Very effective	71%[d]		
Excellent and good	95%[e], 84%[c]		
Very effective and effective		80%[b], 90%[f]	
Good and fair			59%[g]
Excellent and good			20%[g]

[a]Green et al. (1984)
[b]Franklin and Powell (1993)
[c]Andelt and Hopper (2000)
[d]Green and Woodruff (1988)
[e]Andelt (1992)
[f]Meadows and Knowlton (2000)
[g]Walton and Feild (1989)

devices, trapping, snaring, M-44s, denning (locating the dens of depredating coyotes and killing the pups and/or adults), aerial hunting, ground shooting, hunting with decoy dogs, livestock protection collars, and poison baits have been used to reduce predation on livestock (Andelt, 1996). Poison baits were withdrawn from use in 1972 (Andelt, 1996) and use of some methods such as trapping, snaring, M-44s, gas cartridges for denning coyotes, and livestock protection collars have been restricted or eliminated by ballot initiatives in some states such as Arizona, California, Colorado, and Massachusetts (Manfredo et al., 1999). The public also has rated guarding animals as more acceptable than most other techniques for reducing predation (Arthur, 1981; Reiter et al., 1999). Thus, guarding animals are one of the few remaining successful techniques, in some states, that livestock producers can use to mitigate predation. However, guarding animals are not a cure for all problems with predators. Their effectiveness is influenced by a variety of factors and their use requires a commitment by their owners. Some livestock producers continue to require other animal damage-control measures in addition to guarding animals.

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