Managing Wolf Depredation in the United States: Past, Present, and Future

Stewart Breck[1] *and Tom Meier*[2]

[1]*USDA-Wildlife Services-National Wildlife Research Center, 4101 Laporte Ave., Fort Collins, CO 80521*
[2]*U. S. Fish and Wildlife Service, c/o Montana Fish, Wildlife & Parks, 490 N. Meridian, Kalispell, MT 59901*

Introduction

With the successful recolonization and reintroduction of wolves (*Canis lupus*) in parts of the western United States (Bangs and Fritts, 1996; Bangs et al., 1998) and the natural expansion of wolves in the upper Midwest (Fuller et al., 1992; Thiel, 2001), managing conflicts between wolves and livestock is a growing issue for livestock producers, resource professionals, and the general public (Mech, 1996). Unlike the coyote, (*Canis latrans*) where a great deal is known regarding the biology and ecology of depredation and methods for managing it (Knowlton et al., 1999), very little is known regarding patterns and processes of wolves preying on livestock and effective ways to mitigate this conflict. Understanding the ramifications of growing wolf populations for livestock production and successfully managing these problems will require knowledge of depredation patterns, wolf ecology, livestock husbandry, and the effectiveness of different tools and techniques to manage wolves. As wolf populations expand into more agricultural areas (Mech et al., 2000) such knowledge will become increasingly important.

Here historic records were compared to current data on wolf depredation rates and wolf management techniques relative to the wolf's status on the endangered species list. The objectives were to synthesize the history of wolf depredation and management, present current data of wolf impacts on livestock, and speculate on the future management of wolves so that producers can consider the ramifications of a growing wolf population and possible mechanisms for decreasing the threat.

Methods

A Web of Science search was performed for articles published on wolf depredation in the United States and manually searched bibliographies of relevant published articles. The literature search included all relevant combinations of the following keywords: *wolf, livestock, depredation, predation, and domestic animals*. From this literature, data were compiled for the following parameters: wolf population status, depredation rates, amount of compensation paid, and control actions taken. Depredation rates are presented as the number of livestock killed by wolves divided by the total livestock available within wolf range.

Data were compiled for the years 2000 to 2002 on the same parameters mentioned above. Statistics on cattle and sheep distribution (*http://www.usda.gov/nass/*) were used to estimate the number of cattle and sheep within wolf range. Annual USDA-Wildlife Services annual reports from each state were employed to determine the number of cattle and sheep killed by wolves each year. Kills were verified by specialists trained in doing field necropsies to determine cause of death and do not reflect those animals that were determined to be probable or possible kills. Accordingly, the data are conservative. Estimates of wolf population size, number of wolves killed each year, and number of wolves moved each year were gathered from one of the following sources: US Fish and Wildlife Service, Interagency Rocky Mountain wolf recovery reports (USFWS et al., 2003); Wisconsin Department of Natural Resources annual reports (Wydeven et al., 2003); Michigan Department of Natural Resources (Michigan DNR, 1997); and USDA Wildlife Services-Minnesota annual reports (Paul, 2002). The amount of compensation paid in each state was determined for wolf kills through one of the following sources: Minnesota Department of Agriculture, Wisconsin Department of Natural Resources, or Defenders of Wildlife.

Results and Discussion

Wolf Depredation and Wolf Management Prior to the Endangered Species Act

There was very little reliable information regarding the impact of wolves on livestock and factors that affected this interaction before the 1970s. Wolves certainly killed domestic animals and apparently caused considerable damage in certain areas (Bailey, 1907; Young and Goldman, 1944; Brown, 1983). But the accounts were generally anecdotal, possibly exaggerated, and usually did not consider ecological and biological aspects that may have influenced wolf-livestock relationships. The paradigm during this period was that wolves should be eradicated in part because they killed livestock (Lopez, 1978; Fritts, 1982; McIntyre, 1995). Eradication was accomplished primarily through the broad use of poison (e.g., strychnine, thallium sulfate, sodium monofluoroacetate-compound 1080, and cyanide) in conjunction with trapping (e.g., pitfalls, snares, steel traps), denning (finding dens and killing all animals associated with the den), aerial shooting, and sport hunting (Brown, 1983; Cluff and Murray, 1995; McIntyre, 1995). Initially the eradication efforts were financed by livestock producers and state bounty programs that supported professional "wolfers" but because of inefficiency and

Table 1. Mean values for 2000 to 2002 of wolf population, number of wolves killed or moved annually, and compensation paid annually in states with wolves.

	Wolf population	# Wolves killed annually	# Wolves moved annually	Annual compensation
MN	2,600	134	0	$ 75,251
WI	305	0	9	$ 52,280
MI	283	0	5	$ 1,323
MT	134	14	8	$ 23,093
WY	188	4	0	$ 15,224
ID	234	11	4	$ 12,141
NM/AZ	29	0	4	$ 6,251
Sum	**3,773**	**163**	**30**	**$185,563**

fraud, the U.S. Biological Survey hired professional trappers in the early 20th century to remove wolves primarily in the western United States (Lopez, 1978; Brown, 1983; McIntyre, 1995.). By the early 1970s, wolf eradication was nearly complete in the United States except for a small population that remained in remote wilderness of northern Minnesota. Throughout this period other methods occasionally employed to decrease depredation were fencing, shepherding, and improved husbandry (Brown, 1983).

During the 1800s and early 1900s, densities of native ungulates (deer, *Odocoileus* sp.; elk, *Cervus elaphus*; bison, *Bison bison*; and antelope, *Antilocapra americana*) were dramatically reduced through unregulated hunting. Concomitantly, densities of domestic livestock were dramatically increased throughout much of the United States. These changes in ungulate composition and density very likely increased the rate at which wolves killed livestock and contributed to the wolf's reputation as a livestock killer (Brown, 1983). By the time ungulate populations began to rebound in the later 20th century, most wolves had been eradicated. Because large populations of native ungulates and abundant livestock have never been studied in relationship to wolves, there is little known about the impacts that wolves might have on these simultaneously present native game and livestock populations.

Recovering Wolf Populations (1974-2002)

In 1974, wolves were placed on the Endangered Species List, and, as such, lethal control of wolves subsided. In 1978 the wolf's status was changed to threatened in Minnesota to allow federal biologists more flexibility with controlling problem individuals (Fritts, 1982). Otherwise, wolves remained endangered in the lower 48 states. As a result of protection, and despite the 1978 change in this state, the Minnesota wolf population grew steadily from approximately 1000 in 1974 to 2500 in 1998 (Fuller et al., 1992; Berg and Benson, 1999). In the late 1970s and early 1980s, dispersing wolves from Minnesota began colonizing parts of Wisconsin (Wydeven et al., 1995; Thiel, 2001) and Michigan (Michigan DNR, 1997). Populations grew steadily in each state and numbered approximately 330 in each state in 2002.

In the western United States, wolves dispersed from Canada in the late 1970s and began to naturally colonize northwestern Montana (Ream et al., 1989; Pletscher et al., 1997). In 1995 and 1996, wolves from Canada were reintroduced into Yellowstone National Park and central Idaho as experimental non-essential populations. This designation allowed greater flexibility to manage problem wolves despite their status as endangered species. Wolf populations grew steadily in Idaho, Wyoming, and Montana through 2002, to where they occupied most remote areas in these states and were becoming more common in agricultural areas (USFWS et al., 2003).

Depredation Rates

The first studies of the impact of wolves on livestock began in Minnesota and are detailed in Fritts (1982) and Fritts et al. (1992). Mack et al. (1992) summarized data from this work and found that in Minnesota from 1979 to 1991, annual depredation rates averaged 0.12 cattle/1,000 available (range: 0.04 to 0.18) and 2.37 sheep/1000 available (range: 0.03 to 7.04) (Table 2). Our data for Minnesota from 2000 to 2002 showed a mean depredation rate of 0.22 cattle/1000 available (range: 0.17 to 0.26) and 1.81 sheep/1000 available (range: 0.33 to 3.84) (Table 3).

In Montana, Mack et al. (1992)

Table 2. Wolf depredation on cattle and sheep in northern Minnesota, 1979 to 1991 (from Mack et al., 1992 and Paul, 2001.)

	Number of Livestock				Losses/1000 Available	
	Available		Killed			
Year	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
1979	220,970	30,839	17	1	0.08	0.03
1980	225,244	32,950	16	56	0.07	1.70
1981	241,291	39,569	30	110	0.12	2.78
1982	241,742	34,698	24	12	0.10	0.35
1983	242,156	29,827	35	29	0.15	0.97
1984	242,589	24,956	10	92	0.04	3.69
1985	243,021	20,085	23	75	0.10	3.73
1986	220,141	15,904	26	13	0.12	0.82
1987	220,141	15,904	24	9	0.11	0.57
1988	220,141	15,904	31	68	0.14	4.28
1989	220,141	15,904	40	47	0.18	2.96
1990	220,141	15,904	37	112	0.17	7.04
1991	220,141	15,904	35	31	0.16	1.95
Mean	**229,066**	**23,719**	**27**	**50**	**0.12**	**2.37**

Table 3. Number of livestock available and killed by wolves and depredation rate in Minnesota, Wisconsin, and Michigan for calendar years 2000 to 2002.

	Number of Livestock				Losses/1000 Available	
	Available		Killed			
State/Year	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
MN 2000	380,000	15,100	95	19	0.25	1.26
MN 2001	380,000	15,100	64	5	0.17	0.33
MN 2002	380,000	15,100	97	58	0.26	3.84
MN Mean	380,000	15,100	85.33	27.33	0.22	1.81
WI 2000	360,000	15,699	6	0	0.02	0.00
WI 2001	360,000	15,699	11	0	0.03	0.00
WI 2002	360,000	15,699	37	7	0.10	0.45
WI Mean	360,000	15,699	18.00	2.33	0.05	0.15
MI 2000	54,000	2,600	2	1	0.04	0.38
MI 2001	54,000	2,600	3	0	0.06	0.00
MI 2002	54,000	2,600	3	0	0.06	0.00
MI Mean	54,000	2,600	2.67	0.33	0.05	0.13

summarized depredation rates of colonizing wolves from 1987 to 1991 and calculated a mean depredation rate of 0.04 cattle/1000 available (range: 0.0 to 0.08) and 0.21 sheep/1000 available (range: 0.0 to 0.88) (Table 4). From 2000 to 2002, we calculated a mean depredation rate of 0.02 cattle/1000 available (range: 0.02 to 0.03) and 0.59 sheep/1000 available (range: 0.09 to 1.05) (Table 5). Overall, from 2000 to 2002, wolf range in the lower 48 states exposed approximately 1,894,000 cattle and 208,649 sheep to the presence of wolves. There were about 3,773 wolves that killed an average of 153 cattle and 136 sheep per year.

The losses we report were those verified by USDA/APHIS/Wildlife Services; actual losses were greater by an unknown amount. This is an important area of research because compensation programs were primarily based on the number of verified losses. From 2000 to 2002, an average of $185,564 per year was paid in compensation for livestock losses by state governments and Defenders of Wildlife (Table 1). Oakleaf et al. (2003) estimated that the detection rate of cattle killed by predators reflected one-eighth of the actual losses to wolves within their study system in Idaho. They also speculated that the detection rate varied depending on the type of terrain and vegetation characteristics of the grazing allotment (i.e., less rugged and less timbered country would have higher detection rates).

Several patterns emerge from these results. First, the overall impact of wolves on the livestock industry was small relative to other factors, such as disease, coyote depredation, birthing problems, weather, and accidents. However, our analysis does not consider specific spatial location of kills and the degree to which kills were clustered for particular producers. Often it is found that kills are relegated to a few ranches (i.e., hot spots) and that wolves can have a significant economic impact on these individual operations. A number of studies of livestock losses to carnivores demonstrate the presence of hot spots, or small areas that have recurring attacks on livestock by carnivores (Fritts et al., 1992; Cozza et al., 1996). For example, Stahl et al. (2001) studied lynx attacks on sheep in France and found that certain geographical areas that covered only 0.3 to 4.5% of the total area where attacks occurred accounted for 33 to 69% of the attacks. A number of factors are hypothesized for causing hot spots, including individual problem predators, herding techniques, the abundance and availability of wild and domestic prey, habitat characteristics, and the abundance of predators. Mech et al. (2000) compared Minnesota farms that experience chronic depredation by wolves killing cattle to nearby farms without chronic problems. Of 11 farm characteristics measured they found that chronic losses occurred on larger farms, farms that had more cattle, and farms that had herds farther from human dwellings. No other habitat or husbandry practices were found to differ significantly between depredated and non-depredated farms; whether or not these are general patterns that hold true for wolves in other geographical areas is unknown.

Second, the rate of depredation remained relatively constant for Minnesota (1979 to 2002) and Montana (1987 to 2002). These data should be interpreted cautiously because of the uncertainty associated with the estimate of the number of cattle "available" to wolves. But assuming depredation rates were fairly accurate, these data indicate that the size of the wolf population did not affect the rate at which they killed livestock. It is possible that this rate may increase in the future as wolf populations continue to grow and expand into agricultural areas where the availability of livestock and natural prey are different than in more remote wilderness areas. Mech (1998) analyzed this issue and recommended consideration of pre-emptive control to reduce economic cost of controlling wolf populations that are growing into agricultural areas.

Table 4. Wolf depredation on cattle and sheep in northwestern Montana, 1987 to 1991 (from Mack et al., 1992 and U.S. Fish and Wildlife Service et al., 2003)

	Number of Livestock				Losses/1000 Available	
	Available		Killed			
Year	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
1987	75,067	11,338	6	10	0.08	0.88
1988	75,067	11,338	0	0	0.00	0.00
1989	75,067	11,338	3	0	0.04	0.00
1990	75,067	11,338	5	0	0.07	0.00
1991	75,067	11,338	2	2	0.03	0.18
Mean	75,067	11,338	3	2	0.04	0.21

Table 5. Number of livestock available and killed by wolves and depredation rate in Montana, Wyoming, and Idaho for calendar years 2000 to 2002.

	Number of Livestock				Losses/1000 Available	
	Available		Killed			
State/Year	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
MT 2000	750,000	80,000	14	7	0.02	0.09
MT 2001	750,000	80,000	12	50	0.02	0.63
MT 2002	750,000	80,000	20	84	0.03	1.05
MT Mean	750,000	80,000	15.33	47.00	0.02	0.59
WY 2000	80,000	50,000	3	25	0.04	0.50
WY 2001	80,000	50,000	18	34	0.23	0.68
WY2002	80,000	50,000	23	0	0.29	0.00
WY Mean	80,000	50,000	14.67	19.67	0.18	0.39
ID 2000	210,000	25,000	15	48	0.07	1.92
ID 2001	210,000	25,000	10	54	0.05	2.16
ID 2002	210,000	25,000	9	15	0.04	0.60
ID Mean	210,000	25,000	11.33	39.00	0.05	1.56

Last, our data demonstrate that sheep were more vulnerable to attack by wolves than cattle (sheep depredation rates were 2 to 30 times higher than cattle depredation rates; Tables 2, 3, 4, and 5). The reasons for higher depredation rates on sheep were unknown but may be associated with the generally higher vulnerability of sheep to predators or the fact that sheep flocks tend to be less dispersed than cattle herds, possibly facilitating surplus killing. Of interest is the observation that surplus killing by wolves is commonly associated with sheep but not cattle. Because a single depredation incident, or series of incidents, may cause the death of many sheep, sheep depredation numbers show more erratic, unpredictable variation from year to year than cattle depredation numbers.

Depredation Management Techniques

From a management context, the listing of wolves brought about the development and use of new non-lethal tools and techniques to manage wolves (see Smith et al., 2000a and Smith et al., 2000b for a comprehensive review). These included: translocating problem animals (Fritts, 1982, 1985; U. S. Fish and Wildlife Service et al., 2003) utilizing scare devices (Shivik and Martin, 2001; Shivik et al., 2003; Breck et al., 2002), dogs (Coppinger and Coppinger, 1995), barriers (Musiani and Visalberghi, 2001; Musiani et al., 2003), and improving livestock husbandry (Fritts et al., 1992; Mech et al. 2000). Translocation was fairly effective at stopping depredation problems but was expensive and time consuming and relied upon there being vacant areas available to release captured animals. This practice was phased out in all recovery areas as populations grew. The effectiveness of non-lethal tools, such as scare devices and fladry, varied but in general worked for short periods (a few weeks to a few months) and only in small areas. In many situations with problem wolves, non-lethal techniques were initially utilized until they failed at which time lethal control was implemented.

Little is known about how altering livestock husbandry would affect depredation patterns, but it offers promise as to a long-term, non-lethal solution in some situations, especially in areas where livestock are grazed on open range with little management. Alteration to husbandry might include aggregating livestock, managing birthing dates so young are not born on the open range, and herding vulnerable animals at night. Robel et al. (1981) evaluated the effectiveness of several husbandry methods for reducing sheep losses to coyotes by correlating the number of sheep killed to a number of factors that varied among 109 sheep producers in Kansas. Producers experienced less predation loss when they hauled away sheep carcasses, lambed during particular seasons, confined flocks of sheep to corrals, and maintained larger flock sizes. Evidence from Europe also suggests the importance of husbandry. Greater losses of livestock to carnivores occurred in Norway, where sheep were entirely free-ranging and unattended, than in France, where livestock were constantly herded or confined at night (Stahl et al., 2002). Though these and other studies suggest husbandry can be effective for reducing conflict with carnivores, our knowledge regarding husbandry and its effectiveness with different carnivore species, especially wolves, is very limited (Knowlton et al., 1999). It is also important to consider the increased costs and possible deleterious consequences associated with altering husbandry practices (e.g., confinement of livestock may lead to overgrazing) but little research has been done on this topic.

Lethal control of problem individuals and packs became more common in all recovery areas as wolf populations grew. Lethal removal usually was implemented when non-lethal procedures were impractical or ineffective. During 2000 to 2002, an average of 163 wolves were killed annually in the contiguous United States (primarily through trapping) in contrast to none or a few during the earlier years of recovery. It is likely that as wolf populations continue to grow, lethal control will be used more often to control problem wolves. Lethal control of wolves was primarily carried out by federal biologists and managers, and this is likely to remain the paradigm for some time, even after wolves are delisted. Depredation management from 1974 to 2002 was related to the size of a recovering population. At small population sizes, much time and effort was devoted towards minimizing depredation problems through non-lethal management, but as populations grew, lethal removal of selected individuals or packs became more prevalent.

After Delisting

The initial listing of wolves as endangered species in 1974 delineated a critical juncture for the way wolves were managed in the United States. It is likely that the impending delisting of wolves from the endangered species list will present another critical period in that lethal management will become more common in areas where recovered wolf populations are at sustainable levels.

The amount of lethal control allowed, how it is carried out and by whom will likely vary depending upon how individual states set up their individual management plans. In the short term, most wolf control is likely to continue to be done by USDA Wildlife Services, under arrangements with the states similar to those for coyote control. When delisting occurs, it is likely that greater authority will be given to the local communities that have to interact most closely with wolves. Non-lethal control will likely be de-emphasized because of the high costs and limited effectiveness, although research into long-term, non-lethal solutions will likely continue because of the strong interest in alternative management strategies.

Future research regarding lethal control will focus on determining if problem individuals exist and figuring out ways to selectively remove these animals. Problem animals are those individuals that kill more livestock per encounter than other individuals within the population (Linnell et al., 1999). Problem individuals are known to exist for a wide range of carnivores including grizzly bears (Anderson et al., 2002), coyotes (Till and Knowlton, 1983; Conner et al., 1998; Sacks et al., 1999), lynx (Stahl et al., 2002), wolverine (Landa et al., 1999), and jaguars (Rabinowitz, 1986). However for wolves it is difficult to determine whether or not problem individuals exist because of the social nature of packs. Thus it may be more realistic to investigate whether or not problem packs develop. If so, the causal mechanism leading to the development of problem packs would be important to investigate. Understanding what influences carnivores to attack and kill livestock will aid in the development of tools and techniques that managers can use to mitigate problems. It is likely that the most significant advances will unite knowledge of livestock husbandry, technology, and carnivore behavior and ecology.

Literature Cited

Anderson, Jr. C. R., Ternent, M. A., and Moody, D. S. 2002. Grizzly bear-cattle interactions on two grazing allotments in northwest Wyoming. Ursus 13:153-162.

Bailey, V. 1907 . Wolves in relation to stock, game, and the national forest reserves. Forest Service Bulletin 72, U.S. Department of Agriculture: 31 pages.

Bangs, E. E. and Fritts, S. H. 1996. Reintroducing the gray wolf to central Idaho and Yellowstone National Park. Wildlife Society Bulletin 24:402-413.

Bangs, E. E., Fritts, S. H., Fontaine, J. A., Smith, D. W., Murphy, K. M., Mack, C. M. and Niemeyer C. C. 1998. Status of gray wolf restoration in Montana, Idaho, and Wyoming. Wildlife Society Bulletin 26:785-798.

Berg, W. E., and Benson, S. 1999. Updated wolf population estimate for Minnesota, 1997-1998. Minnesota Department of Natural Resources, Grand Rapids, MN.

Breck, S. W., Williamson, R., Niemeyer, C., and Shivik, J. A. 2002. Nonlethal radio activated guard for deterring wolf depredation in Idaho: summary and call for research. Proceedings Vertebrate Pest Conference 20:223-226.

Brown, D. E. 1983. The wolf in the southwest. The making of an endangered species. University of Arizona Press, Tucson, AZ.

Cluff, D. H. and Murray, D. L. 1995. Review of wolf control methods in North America. In: Ecology and conservation of wolves in a changing world. Edited by Carbyn L. N., S.H. Fritts, and D.R. Seip. Canadian Circumpolar Institute, Occasional Publication 35, Edmonton, Alberta. pp. 491-504.

Conner, M. M., Jaeger, M. M., Weller, T. J., and McCullough, D. R. 1998. Impact of coyote removal on sheep depredation in northern California. Journal of Wildlife Management 62:690-699.

Coppinger R. and Coppinger L. 1995. Interactions between livestock guarding dogs and wolves. In: Ecology and conservation of wolves in a changing world. Edited by L.N. Carbyn, S.H. Fritts, and D.R. Seip. Canadian Circumpolar Institute, Occasional Publication 35, Edmonton, Alberta. pp. 523-526.

Cozza, K., Fico, R. and Battistini, M. L. 1996. The damage-conservation interface illustrated by predation on domestic livestock in central Italy. Biological Conservation 78:329-336.

Fritts, S. H. 1982. Wolf depredation on livestock in Minnesota. U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 145. 11 pp.

Fritts, S. H. 1985. Can relocated wolves survive? Wildlife Society Bulletin 13:459-463.

Fritts, S. H., W. J. Paul, L. D. Mech, and D. P. Scott. 1992. Trends and management of wolf-livestock conflicts in Minnesota. Resource Publ. 181. U. S. Fish and Wildlife Service, Washington, D. C. 27pp.

Fuller, T. K., W. E. Berg, G. L. Radde, M. S. Lenarz, and G. B. Joselyn. 1992. A history and current estimate of wolf distribution and numbers in Minnesota. Wildlife Society Bulletin 20:42-55.

Knowlton, F. F., Gese, E. M., and Jaeger, M. M. 1999. Coyote depredation control: an interface between biology and management. Journal of Range Management 52:398-412.

Landa, A., Gudvangen, K., Swenson, J. E. and Roskaft, E. 1999. Factors associated with wolverine Gulo gulo predation on domestic sheep. Journal of Applied Ecology 36:963-973.

Linnell, J. D. C., Odden, J., Smith, M. E., Aanes, R., and Swenson, J. E. 1999. Large carnivores that kill livestock: do "problem individuals" really exist? Wildlife Society Bulletin 27:698-705.

Lopez, B. H. 1978. Of wolves and men. Charles Scribner's Sons, New York. 151 p.

Mack, J. A., Brewster, W. G., and Fritts, W. H. 1992. A review of wolf depredation on livestock and implications for the Yellowstone area. pp. 5-21 through 5-44. In: Wolves for Yellowstone? A report to the United States Congress Volume IV Research and Analysis, Edited by J.D. Varley and W.G. Brewster. National Park Service, Yellowstone National Park.

McIntyre, R. 1995. War against the wolf: America's campaign to exterminate the wolf. Voyageur Press, Stillwater, MN.

Mech, L. D. 1996. A new era for carnivore conservation. Wildlife Society Bulletin 24: 397-401.

Mech, L. D. 1998. Estimated costs of maintaining a recovered wolf population in agricultural regions of

Minnesota. Wildlife Society Bulletin 26:817-822.
Mech, L. D., Harper, E. K., Meier, T. J., and Paul, W. J. 2000. Assessing factors that may predispose Minnesota farms to wolf depredations on cattle. Wildlife Society Bulletin 28:623-629.
Michigan Department of Natural Resources. 1997. Michigan gray wolf recovery and management plan. Wildlife Division, Michigan Department of Natural Resources, Lansing.
Musiani, M., Mamo, C., Boitani, L., Callaghan, C., Gates, C. C., Mattei, L., Visalberghi, E., Breck, S., and Volpi, G. 2003. Wolf depredation trends and the use of barriers to protect livestock in western North America. Conservation Biology 17:1538-1547
Musiani, M. and Visalberghi, E. 2001. Effectiveness of fladry on wolves in captivity. Wildlife Society Bulletin 29:91-98.
Oakleaf, J. K., C. Mack, and D. L. Murray, 2003. Effects of wolves on livestock calf survival and movements in central Idaho. Journal of Wildlife Management 67:299-306.
Paul, W. J. 2002. Wolf depredation on livestock in Minnesota. Annual update of statistics. USDA, APHIS, Wildlife Services, 34912 U.S. Hwy. 2, Grand Rapids, MN 55744.
Pletscher, D. H., Ream, R. R., Boyd, D. K., and Blakesley, A. J. 1997. Population dynamics of a recolonizing wolf population in the Rocky Mountains. Journal of Wildlife Management 61:459-465.
Rabinowitz, A. R. 1986. Jaguar predation on domestic livestock in Belize. Wildlife Society Bulletin 14:170-174.
Ream, R. R., Fairchild, W., Boyd, D. K., and Blakesley, A. J. 1989. First wolf den in western United States in recent history. Northwestern Naturalist 70:39-40.
Robel, R. J., Dayton, A. D., Henderson, F. R., Meduna, R. L., and Spaeth, C. W. 1981. Relationships between husbandry methods and sheep losses to canine predators. Journal of Wildlife Management 45:894-911.
Sacks, B. N., Blejwas, K. M., and Jaeger, M. M. 1999. Relative vulnerability of coyotes to removal methods on a northern California ranch. Journal of Wildlife Management 63:939-949.
Shivik, J. A. and Martin, D. J. 2001. Aversive and disruptive stimulus applications for managing predation. Proceedings of the Eastern Wildlife Damage Management Conference 9:111-119.
Shivik, J. A., Treves, A., and Callahan, P. 2003. Non-lethal techniques: primary and secondary repellents for managing predation. Conservation Biology 17:1531-1537.
Smith, M. E., Linnell, J. D. C., Odden, J., and Swenson, J. E. 2000a. Review of methods to reduce livestock depredation: I. guardian animals. Acta Agriculturae Scandinavica Section a-Animal Science 50:279-290.
Smith, M. E., Linnell, J. D. C., Odden, J., and Swenson, J. E. 2000b. Review of methods to reduce livestock depredation II. aversive conditioning, deterrents and repellents. Acta Agriculturae Scandinavica Section a-Animal Science 50:304-315.
Stahl, P., Vandel, J. M., Herrenschmidt, V., and Migot, P. 2001. Predation on livestock by an expanding reintroduced lynx population: long-term trend and spatial variability. Journal of Applied Ecology 38:674-687.
Stahl, P., Vandel, J. M., Ruette, S., Coat, L., Coat, Y., and Balestra, L. 2002. Factors affecting lynx predation on sheep in the French Jura. Journal of Applied Ecology 39:204-216.
Till, J. A. and Knowlton, F. F. 1983. Efficacy of denning in alleviating coyote depredations upon domestic sheep. Journal of Wildlife Management 47:1018-1025.
Thiel, R. P. 2001. Keepers of the wolves. The early years of wolf recovery in Wisconsin. University of Wisconsin Press, Madison, Wisconsin. 242 p.
U. S. Fish and Wildlife Service, Nez Perce Tribe, National Park Service, and USDA Wildlife Services. 2003. Rocky Mountain wolf recovery 2002 annual report. T. Meier, ed. USFWS, Ecological Services, 100 N Park, Suite 320, Helena MT 64 pp.
Wydeven, A. P., Schultz, R. N., and Thiel, R. P. 1995. Monitoring of a gray wolf (Canis lupus) population in Wisconsin, 1979-1991. Pp. 147-156 in L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds., Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Edmonton, Alberta.
Wydeven, A. P., J. E. Wiedenhoeft, R. L. Schultz, R. P. Thiel, S. R. Boles, W. H. Hall Jr, and E. Heilhecker. 2003. Progress report of wolf population monitoring in Wisconsin for the period October 2002 – March 2003. Wisconsin Department of Natural Resources, Park Falls, Wisconsin.
Young, S. P. and Goldman E. A. 1944. The wolves of North America. American Wildlife Institute, Washington, D. C.