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Wolves and Livestock: A review of tools to deter livestock predation and a case study of a proactive wolf conflict mitigation program developed in the Blackfoot Valley, Montana

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By

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Abstract

The recent recovery of wolves in the Northern Rocky Mountains (NRM) was met with opposition from the ranching communities throughout Montana. This was not surprising, due to the fact that wolves are feared as a predator of livestock and therefore represent a direct economic loss for ranchers that experience depredations by wolves. Wolves are also revered as a native predator that have top down effects upon natural prey species. This in turn affects the web of plants and animals that make up natural ecosystems. This fact, as well as the strong emotional connection that some stakeholders have to wolves creates a tense value laden debate when wolves come into conflict with humans. Non-lethal conflict mitigation tools have been developed, funded, and implemented in several communities throughout the NRM; in hopes of decreasing the polarization that once ruled the debate between the stakeholders. Montana ranchers have always been fiercely independent, yet many have found themselves partnering with conservation organizations to experiment with a new model of predator management that includes non-lethal tools. This literature review highlights the effectiveness, limitations, and local applicability of various non-lethal tools. A case study of a collaborative program is also included that was developed in the Blackfoot Watershed of western Montana. Wolves, livestock and people will continue to interact in the NRM, finding a way to reduce the conflict will help assure long term solutions that respect all the values placed on wolves.

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Table of Contents

Section 1. Introduction

The gray wolf (*Canis lupus*) is a top carnivore native to Montana. Wild ungulates and ecosystems evolved with this predator but European settlement of North America led to the near extermination of wolves and their natural prey by the 1930s (Betsche and Ripple 2009; Young and Goldman 1944). European settlers arrived with domestic ungulates which attributed to habitat degradation through overgrazing, while unregulated hunting of wild ungulates led to their near replacement by livestock. Prey switching occurred and wolves were trapped, poisoned, and shot to support burgeoning economies that relied on utilization of rangeland resources with domestic ungulates (Curnow 1969). The re-establishment of a viable wolf population in the Northern Rocky Mountains (NRM) as mandated by the Endangered Species Act of 1974 (ESA) has resulted in growing tensions among diverse stakeholder groups that all value wolves for different social, biological, and economic reasons (United States Fish and Wildlife Service [USFWS] 1987). As a result of their re-colonization of the western U.S., wolves are once again feared as a predator of wild and domestic ungulates. Today, few natural resource issues are more hotly debated than the recovery of wolves into the NRM.

Ranchers that experience direct and indirect economic losses to wolves will continue to question the need for wolves to exist across the NRM (Fritts et al. 1995, Musiani et al. 2005). Wolf management at the state and federal level has become a persistent issue represented in popular media and peer reviewed literature; resulting in dynamic debates that consider the efficacy of lethal population control and non-lethal conflict mitigation tools (Bangs et al. 2006, Harper et al. 2008). Wolves in Montana will continue to have an economic impact on some livestock producers. This fact will allow conservation minded stakeholders to continue collaborating with imperiled ranchers to develop innovative tools that might counteract predation loss (Shivik 2004).

Wolf depredation of livestock has resulted in considerable effort by the United States Department of Agriculture Wildlife Service (USDA-WS) to support and conduct lethal wolf control of depredating individuals, yet lethal control is not acceptable wolf management to many citizens (Treves and Naughton-Treves 2005, Reiter et al. 1999). Lethal control of wolves runs counter to the USFWS mandate to recover endangered species listed under the Endangered Species Act of 1974 (USFWS 1987). Wolves have exposed the realities of this complex social issue as wolf managers try to balance the spectrum of values placed on wolves.

Compensation programs have been funded at the state level in an attempt to reduce the economic hardship that is felt by the ranching community and to build social tolerance of wolves when they utilize livestock as a prey species (Montag et al. 2003, Fischer 1989). Concurrently in Montana; non-governmental organizations, USDA-WS agents, Montana Fish Wildlife and Parks wolf conflict specialists, and watershed groups are funding and implementing a variety of lethal and non-lethal tools to build social tolerance of wolves and wolf management and to reduce the loss of both wolves and livestock (Sime et al. 2010, Bangs et al. 2006, USFWS 1987, USFWS 1988).

The complexity of society's relationship with wolves and the need for more efficient and effective means of reducing livestock losses to wolves provides the basis for my professional paper. The objective will be to review literature that explores the efficacy of a variety of non-lethal tools for mitigating wolf and livestock conflicts as a means of reducing the polarization surrounding wolf recovery in the NRM. A review of these various tools will provide an understanding of the local applicability of each method and potential societal benefits of proactive non-lethal mitigation of wolf conflict with livestock. I also discuss my experiences and lessons learned while implementing a pilot livestock and wolf monitoring program over the past two years in the Blackfoot Valley of western Montana, USA under the guidance and auspices of the Blackfoot Challenge (BC).

This paper is divided into four sections. The first section presents background information concerning wolf reintroduction into the NRM and a review of the level of depredation by wolves that ranchers have experienced in Montana and the Blackfoot Watershed. The second section is a literature review of some of the non-lethal conflict prevention tools available to ranchers in the NRM. The third section considers the various components of a wolf and cattle monitoring and proactive conflict mitigation program that I helped develop with the Blackfoot Challenge. The fourth section provides a conclusion and summary of the lessons learned through my involvement with the Blackfoot Challenge.

Background

Montana wolf populations are considered recovered based on federal recovery goals achieved in 2002 (USFWS et al. 2003). This success was made possible through favorable policy protecting wolves, the natural dispersal of wolf populations from Canada, and the reintroduction of wolves into Yellowstone National Park and central Idaho wilderness in the winters of 1995-96 with the release of 66 wolves captured in Canada (Bangs et al. 2006). The population of gray wolves in Montana increased from 15 individuals and one confirmed breeding pair in 1986 to a minimum of 566 wolves in 2010 which included a minimum of 35 confirmed breeding pairs (Ream et al. 1989; Sime et al. 2011). Initial patterns of wolf re-colonization in the NRM seemed to suggest that suitable wolf habitat was located on forested public lands with healthy ungulate prey densities and low levels of human development (USFWS et al. 2003).

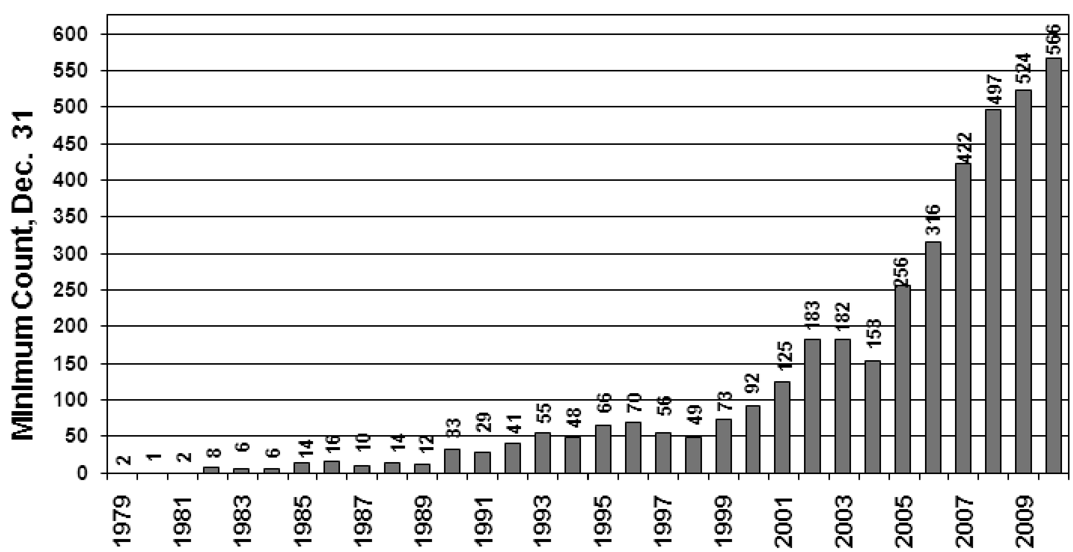

Figure 1. Minimum number of wolves in Montana between 1979-2010 (Sime et al 2011).

Wolves moving south out of Canada came into conflict with livestock in the years prior to the 1995-96 reintroduction effort, resulting in 16 confirmed depredations (Niemeyer et al. 1994). The magnitude of livestock depredation loss has grown since then with 163 USDA-WS confirmed livestock mortalities attributed to wolves in Montana in 2010 (Sime et al. 2011). While confirmed depredations account for some of the losses that can be attributed to wolves; undiscovered death losses, stress from predator/prey interactions resulting in weight loss, and a reduction in fertility rates due to elevated stress hormone levels are also being proposed as potential productivity losses that ranchers could experience when wolves and livestock interact (Oakleaf et al. 2003; Laporte et al. 2010). Confirmed lethal conflicts between wolves and livestock in 2010 resulted in USDA-WS lethal removal of 141 wolves, which accounted for 79% of all confirmed wolf mortalities in Montana for that year (Sime et al. 2011). The Blackfoot Watershed has experienced 11 USDA-WS confirmed depredations since the re-colonization of wolves in 2007. Yet, confirmed livestock depredation by wolves represents a fraction of the actual death and productivity losses experienced by livestock producers on a yearly basis (Oakleaf et al. 2003; Laporte et al. 2010; NASS 2006).

A total of 1432 cattle and sheep have been confirmed killed by wolves in Montana between the years of 1987-2010 by USDA-WS (Sime et al. 2011). In the same time period, USDA-WS has lethally removed 724 wolves from the Montana population in response to these livestock losses. Montana livestock producers report an annual population of approximately 2.6 million cattle and 265,000 sheep (NASS 2006). Some ranchers and individuals that consider wild wolf populations to be unacceptable in the NRM focus on this small level of loss as the evidence for eradication efforts. As a result, wildlife managers and their conservation partners have focused on implementing proactive non-lethal conflict mitigation tools as a means of building social tolerance and acceptance of wolves while attempting to reduce seemingly insignificant depredation losses.

YEAR	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	TOTAL
Montana																									
cattle	6	0	3	5	2	1	0	6	3	10	19	10	20	14	12	20	24	36	23	32	75	77	97	87	582
sheep	10	0	0	0	2	0	0	0	0	13	41	0	25	7	50	84	86	91	33	4	27	111	202	64	850
other [3]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	0	3	2	2	14	16	6	11	63
dogs	0	0	0	1	0	0	0	0	4	1	0	1	2	5	2	5	1	4	1	4	3	2	4	2	42

Figure 2. Confirmed wolf depredations of various domestic animals in montana from 1987-2010 (Sime et al. 2011) (3- llama, goats, horses, miniature horses, domestic bison).

Research in Alberta, Canada suggests that both elk and cattle modify their behavior in relation to wolf presence, with potential energetic costs (Laporte et al. 2010). The current compensation fund in Montana considers just the market value of the animal killed (Sime et al. 2010). Society might consider refunding some additional costs (e.g., weight loss and reduced reproduction rates) that might be associated with changes in cattle behaviors that researchers have documented (Laporte et al. 2010). Efforts to empirically prove potential productivity losses to livestock due to wolf presence serves to answer non-consumptive loss questions that surface in public debate, but modeling behavior and extrapolating the results to predict potential loss does not resolve the question of actual productivity losses. The only means of preventing potential loss is to spatially and temporally separate wolves and livestock, which can only be definitively achieved through the separation of the two through management actions that remove either wolves or livestock from areas that they both frequent. Efforts to physically separate the two on public lands in the NRM will only lead to further polarization between ranchers and conservation minded citizens. Collaborative conservation efforts in the NRM that focus on equal access to public resources suggest that the only long term solution requires that livestock and wolves continue to interact on public lands. Society might also consider funding proactive non-lethal conflict mitigation tools that reduce the frequency of encounter between livestock and wolves.

Wolves can have a negative economic impact on some ranching operations in the NRM through productivity losses and direct predation of livestock (Musiani and Muhly 2009). While confirmed livestock losses to wolves remains insignificant to the livestock industry as a whole in Montana, localized losses where chronic depredations or surplus killing occur can have a significant impact on individual ranchers. In the mid 1990s, conservation groups developed compensation schemes that paid ranchers for direct losses of livestock attributed to wolves when the wolf population was at risk of eradication due to low social tolerance of livestock death loss and wolves in general. Yet, compensation schemes have failed to build social tolerance and acceptance of wolves, resulting in a recurring cycle of livestock loss, compensation, and lethal pack removal in areas of chronic conflict (Naughton-Treves et al. 2003). Compensation schemes present moral and ethical challenges to ranchers, often resulting in perverse incentives that do not promote proactive conflict mitigation (Treves et al. 2009). Direct losses to wolves and the compensation paid out for death losses are unlikely to save ranching operations that are teetering close to economic failure due to other economic and market factors (Berger

2006). Yet the fear that wolves will put ranchers out of business remains a consistent mantra within the ranching communities of the NRM.

Human fear of wolves is deeply rooted in myth and childhood stories. This fear has resulted in low social tolerance of wolves, and irrational human behavior that focuses on controlling wildlife rather than attempting to coexist by augmenting our behavior to consider the presence of predators. While this approach to wildlife management was once commonplace throughout the western U.S., we no longer have the luxury of separating ourselves from interacting with wildlife. The recent expansion of urban centers and development of urban interface areas has encroached upon wildlife habitat. Human and wildlife interaction is pervasive throughout the western U.S. and the number of conflicts has increased as the population of people and wildlife grow.

Effective methods of reducing the frequency of encounter between wolves and livestock and focusing efforts in areas of chronic conflict may offer a way to reduce the polarization between interest groups that place widely different values on wolves in the NRM. Non-lethal deterrents can be classified into the following: aversive conditioning techniques, livestock guard animals, separation of livestock from predators using physical barriers, and livestock husbandry practices. This review of some of the tools available to livestock producers can provide an understanding of the local applicability of each method depending upon site specific landscape and livestock operation characteristics. Yet the efficacy of each tool should also consider the societal and psychological benefits of proactively employing non-lethal tools. This approach to collaborative conservation can promote cooperation between groups that hold widely different views for managing conflicts between wolves, livestock, and humans within the rural landscapes of the NRM.

Section 2. Literature Review of Non-Lethal Tools

Introduction

The most promising forms of non-lethal predation management tools are summarized below. They include aversive conditioning techniques, livestock protection animals, separation of livestock from predators using physical barriers, and animal husbandry practices. This review will aid wildlife managers to accurately consider the biological and social benefits of implementing non-lethal alternatives to lethal predator management.

Lethal control is the primary tool used to manage wolf populations (Archibald et al. 1991, Mech et al. 2000). Yet, lethal methods alone have not eliminated wolf depredation of livestock (Fritts et al. 1992, Mech 1995, Musiani et al. 2005). A public opinion survey indicated that most citizens were uncomfortable with lethal control of predators, especially by federal employees (Reiter et al. 1999). Citizens generally preferred the implementation of non-lethal methods whenever feasible (Reiter et al. 1999). This same study also indicated that USDA-WS agents should focus on cooperative efforts that focused on providing technical assistance and research opportunities to private citizens that require the services of USDA-WS animal damage control agents (Reiter et al. 1999). This interview seems to suggest that most citizens support the use of non-lethal methods of reducing predation loss.

Aversive and Disruptive Stimuli Methods

Aversive and disruptive stimuli represent two behavior modification tools that have been used to control wolves utilizing livestock as prey (Shivik and Martin 2001). Disruptive stimuli intend to disrupt predatory behaviors by frightening or startling a carnivore that is near livestock. Habituation occurs if disruptive stimuli do not include a random assortment of sufficiently noxious stimuli (Shivik and Martin 2001). Aversive stimuli are paired in time with a behavior in order to condition a wolf against the behavior, such as attacking or eating livestock (Shivik and Martin 2001). Achieving effective and specific conditioning against behaviors such as attacking cattle has proven to be extremely difficult under natural conditions (Shivik et al. 2002). Flashing lights and sirens in a pasture will not aversively condition wolves to cease entering the pasture; but rather wolves will learn to ignore the stimulus if a desirable food resource is still present (Shivik 2004). Similarly, shooting wolves with rubber bullets when they enter a pasture will not necessarily condition the wolves to generalize and avoid the area; rather they are more likely to learn to avoid the person shooting at them (Shivik 2004). Despite the lack of measurable success of aversive conditioning tools in field situations, ranchers report psychological benefits of implementing non-lethal deterrents (Lance et al. 2010).

Aversive conditioning refers to the elimination of an undesired behavior by associating that behavior with pain or discomfort (Shivik 2004). A variety of scent aversion, noise and light emitting alarm devices, less than lethal munitions, and shock collars have been studied to deter wolves when they are adjacent to or located in livestock pastures (Shivik 2006). In order for these techniques to be effective they have to be sufficiently noxious or painful so that they alter wolf behavior at the exact time that they are in the act of threatening to prey on livestock (Smith et al. 2000). Studies of disruptive and aversive stimuli indicate that wolves readily become habituated to one single deterrent and that a combination has the potential for longer effectiveness due to a neo-phobic response of wolves to new experiences or stimuli (Breck et al. 2011). Effectiveness is dependent upon vigilance on the part of the producer to pursue wolves when they are attacking livestock, thus focusing efforts on wolves that exhibit livestock predation tendencies. Additionally, wildlife managers and researchers may be required to trap, collar and release wolves from depredating packs so that VHF collar dependent aversion tools can be deployed. Ultimately, the goal is to aversively condition wolves from utilizing livestock as prey.

All of the previously mentioned tools require significant monitoring effort that equates to increased human presence in livestock pastures where wolves have been known to frequent. Evaluating the efficacy of one single deterrent may be confounded by the presence of multiple deterrent factors when wolves are pursued by producers monitoring their livestock for wolf presence. The following review will present several of the less than lethal deterrents and aversion tools that have been deployed in the NRM.

Electronic Aversion Collars

Electronic dog training collars have been effectively used by dog trainers to reverse negative behaviors in working dogs as well as in coyotes (Andelt 1999). Researchers surmised that electronic shock collars could be used to deter wolves from preying on livestock. Shivik et al. (2002) tested remotely activated shock collars on wolves from a recently re-colonized wolf pack in the NRM that had killed livestock. Collared wolves were shocked when they approached within a shock zone surrounding calves that were fitted with a collar that activated the shock collar. Unfortunately, the researchers were unable to effectively condition the wolves to not attack and kill livestock due to a variety of logistical and behavioral reasons. These included; equipment/technology malfunction, wariness of wild wolves, availability of appropriate prey items, seasonal limitations, and wildlife policy restrictions (Shivik et al. 2002).

Hawley et al. (2009) revisited the shock collar theory in Wisconsin. They developed a study design that monitored wild wolves fitted with shock collars that activated when they approached a baited scent post within their territory in Wisconsin. The researchers found that the treatment wolves moved 0.7 km away from the scent post location where a transmitter activated the shock collar when the wolf was within 30 m (Hawley et al. 2009). After the treatment period some of the wolves resumed their previous use pattern indicating that the long term effectiveness might be related to factors specific to the wolf or the shock delivery system. Summarizing their results, Hawley et al. (2009) indicated that they would be able to protect a discrete pasture that contained livestock by decreasing the incidence of wolf and livestock interaction by 80%. Gehring et al. (2006) repeated the same study design in Wisconsin and Michigan; they found that treatment wolves decreased their use of the bait sight by 50% while control wolves increased their use by 18%. The following year they found that shocked wolves avoided the bait site for 60 days after the shock period was increased from 14 days to 40 days (Gehring et al. 2006).

Training depredating wolves to avoid calving pastures and other discrete pasture arrangements could lead to favorable use of shock collars for decreasing lethal livestock and wolf interactions. The cost and time commitment of deploying shock collars prior to a depredation requires significant effort on the part of the researcher or wildlife manager resulting in logistical challenges that might preclude the use of shock collars. Managers often choose less time intensive and more effective method of reducing future depredations. Shock collars present psychological dilemmas for humans that are concerned about the ethical treatment of wild animals. Choosing domestic animal production over wild animal persistence will always preclude non-lethal techniques with lethal removal options. NRM wildlife management agencies have adopted aggressive lethal wolf control protocol in the last several years, focused on removing depredating pack members rather than attempting to re-train those individuals to avoid livestock as prey (Sime et al. 2009).

Radio and Motion Activated Guard Devices

Radio and motion activated guard devices are remotely activated light and siren disruptive stimulus devices that intend to deter wolves from discrete locations where livestock might be at risk of wolf predation. Radio activated alarm systems also alert livestock producers to the presence of wolves fitted with VHF radio collars allowing the livestock producer or guard to employ additional non-lethal deterrents. Linhart et al. (1992) determined that pre-programmed automatic electronic guards reduced sheep losses by 60% in a field situation where coyotes were present. A major limitation of automatic or motion activated frightening devices is that individual predators quickly habituate to the stimuli (Koehler et al. 1990, Bomford and O'Brien 1990). Therefore, devices that fire frequently without a link to animal behavior rapidly lose their effectiveness (Shivik and Martin 2001). However, a device that is behavior contingent and includes a random variety of "alarming" noises that activate when target animals exhibit undesirable behavior has the potential to decrease habituation and increase the overall effectiveness of the device (Breck et al. 2002).

Electronic guard devices have often been used in areas such as night bedding grounds and calving yards near ranch buildings. Radio activated guard devices are not intended to be used in open range situations where livestock are widely dispersed (Breck et al. 2002). Breck et al. (2002) deployed radio activated guard devices in Central Idaho and recorded 82 days with no lethal interaction between cattle and wolves. Other pastures in the region that were not similarly protected experienced significant depredations of cattle. The radio activated device randomly selected from a database of thirty noxious sounds that were projected from speakers when a wolf with a radio collar was within a range of 20-300 m from the VHF monitoring device (Breck et al. 2002). Wolves, in this study, did not immediately habituate to the behavior contingent random noise features of this radio activated device.

Radio activated devices are dependent upon wildlife agency effort to deploy radio collars in wolf packs that will potentially come into conflict with livestock. Due to the complexity of the system, time commitment to deploy radio collars, and the cost of the device ($3,800/unit), Radio Activated Guard (RAG) boxes have had limited use in livestock systems in the NRM (Breck et al. 2002). A multi method approach to reducing the frequency of encounter between wolves and livestock has resulted in the least amount of depredations. The associated cost of a multi method management strategy should be considered when assessing the cost benefit analysis of non-lethal predation control. Ranches that have discreet pasture arrangements, defined calving areas, and practice night penning stand the chance of receiving the most benefit from the use of RAG devices. Behavior contingent aversive conditioning with RAG boxes has proven successful at reducing the frequency of encounter between wolves and livestock; therefore they are successful at disrupting wolf predatory behavior.

Less than Lethal Munitions

Rubber bullets, bean bags, and paint balls have been used to inflict pain in a non-lethal manner to wolves when approaching livestock. Cracker shells produce a loud firecracker report when the projectile explodes after traveling through the air for 50-75 m. Pain inflicting and noise deterrents are designed to produce a fright or startle response in wolves when wolves have been detected in areas adjacent to livestock (Shivik 2004). The combination of pain inflicting projectiles and noise makers reinforces the fear that wolves develop for humans.

Effectiveness of less than lethal munitions is dependent upon detection of wolves by producers and effective deployment of the munitions. Bear managers have used a combination of rubber bullets and cracker shells to aversively condition bears from frequenting areas of high human use and potential conflict (Hunt 1984). The same premise is behind attempts to condition wolves from utilizing livestock as a prey species. Successful and safe deployment of munitions requires training and proper use to avoid injury to the wolves and the shooter. Anecdotal evidence indicates that rubber bullets occasionally lodge in shotgun barrels, potentially causing an injurious malfunction if another bullet is fired. Shooting at wolves also requires careful aim so as to not injure the animal's eyes or other parts of the body that could cause permanent and lethal injury.

Cracker shells can also start fires in dry vegetation conditions and certainly all spark or flame producing devices warrant caution.

Less than lethal munitions allow producers to create a sufficiently noxious event that reinforces human presence within livestock herds. This can be especially effective at night when limited light conditions do not allow for careful tracking of exact wolf location. Less than lethal munitions allow for non-injurious hazing of wolves in areas where producers are not allowed to shoot to kill wolves that are observed harassing their livestock. Non-injurious hazing of wolves with munitions provides a psychological benefit to producers as well as targeting individual wolves that frequent livestock pastures.

Scent and Taste Aversion Compounds

Scent and taste aversion compounds provide an alternative to the lethal chemicals whose use led to the near eradication of wolves in the U.S. in the 1930's (Curnow 1969). Sodium fluoroacetate (Compound 1080), a lethal pesticide, was federally banned in the US in 1972 (Lynch and Nass 1981). Lithium chloride, a common emetic, has been applied to livestock carcasses and baits with the intended purpose of producing severe nausea in the carnivore following ingestion (Gustavson 1982). Scent aversion chemicals can be applied to fence posts or systematically applied to areas surrounding a pasture. Compounds commonly used contain concentrated ammonia, capsaicin compounds, or cinnamon; all which have proven effective at reducing coyote predation in field studies (Lehner 1987). None of these compounds have demonstrated long-term or widespread efficacy and several have resulted in harming the sheep (Lehner 1987). Theoretically, aversive conditioning of predators against a selected prey could be a useful tool for wolf managers, especially where wolves are protected under the ESA and management related mortality is undesirable. There continues to be considerable controversy over the efficacy of this technique, with inconsistent results leading to questions about whether an aversion to eating a particular prey species equates to an aversion to killing that prey species (Burns and Connolly 1980, Smith et al. 2000). Field application of scent and taste aversion chemicals is limited and past studies utilized captive carnivores in controlled experiments.

Artificial Territory Marking

Wolves and coyotes use urine and scat to delimit territory boundaries (Peters and Mech 1975). African wild dogs also utilize scent marking to delimit territory indicating that they communicate with con-specifics through chemical signals (Parker 2010). Ausband (2010) developed a pilot project that evaluated the effectiveness of competing pack territory marking in central Idaho in an area that had previous depredation events attributed to wolves. The researcher developed an artificial bio-fence with scat and urine that was obtained from wolf packs outside of the Central Idaho recovery area. Wolf movement patterns were then recorded using GPS enabled radio collars which allowed the researchers to determine if the wolves reacted to the placement of the bio-fence. Preliminary results indicated that the resident wolf packs altered their established movement patterns to avoid the bio-fence (Ausband 2010).

Effectiveness, Cost, and Limitations of Aversive/Disruptive Stimuli

Human activity that is associated with deploying aversive conditioning stimuli in livestock pastures may also have an impact on wolf habituation to livestock pastures. If wolves begin to associate human scent and presence with negative encounters, then the effectiveness of non-lethal tools may be increased by developing a fear of human presence by wolves. All of the previously mention tools require a significant time commitment to ensure that wolves are successfully deterred from livestock pastures. The commitment level required is often times not possible in remote grazing allotments. Habituation does occur, which requires that the tool include a random assortment of noxious sensory stimuli. Long-term application and cost effectiveness of non-lethal deterrents may be difficult to justify as long as livestock are free-ranging and unsupervised on remote grazing allotments where depredations are rarely observed (Smith et al. 2000).

Livestock Protection Dogs (LPD)

Livestock protection dogs have been used in the U.S. since the early 1970s to protect sheep and goats from predators (Andelt 2004). Several factors contributed to this including federal restrictions on the use of 1080 as a pesticide, limited success of existing techniques, and a desire by some to use non-lethal methods to reduce livestock depredations (Green and Woodruff 1999). The use of domesticated dogs to protect livestock can be traced back several thousand years and has resulted in the development of over 40 breeds that have been utilized to protect sheep and goats from wolves and brown bears (*Ursus arctos*) in Europe and Asia (Landry 1999). Livestock producers in Europe have reported that Livestock Protection Dogs (LPDs) are effective at reducing livestock predation by wolves in Europe (Espuno et al. 2004). Investigations into the usefulness of LPDs in the US were led by the US Department of Agriculture Animal and Plant Health Inspection Service (APHIS). This research has assisted producers in understanding which breed of dog are most effective, how to train and rear pups, the cost of acquiring LPD's, and specific landscape and livestock husbandry practices that might limit effectiveness of guard dogs (Linhart et al. 1979; Green et al. 1984).

LPD Breeds

LPD breeds that have demonstrated effectiveness at reducing predation by coyotes and wolves include, but are not limited to Akbash, Anatolian Shepard, Great Pyrenees, Komodor, and Maremma (Andelt, 1999). LPD breeds and individuals are selected for possessing a combination of attentiveness, trustworthiness, and protectiveness which varies between breeds and individuals, though no noticeable difference has been detected between breeds by producers (Coppinger et al. 1988, Green and Woodruff 1988, Marker et al. 2005). Individual dogs that rate low in trustworthiness or exhibit behavioral problems have still proven effective at reducing predation (Marker et al. 2005) Great Pyrenees are the most common breed (57%) of guard dog utilized by U.S. sheep producers (Andelt 1999). Several factors appear to affect LPD efficacy including individual dog traits, training, size of herd protected, and the extent of pasture to be protected (Green and Woodruff 1999). Producer interviews and mail in surveys comprise the majority of data on specific breeds making it difficult to separate breed efficacy from observer bias and training differences.

Reported attacks on LPDs by wolves have increased recently as wolves continue to recover and expand into new areas in the US (Bangs et al. 2005). A total of 139 dogs have been confirmed killed by wolves in the NRM from 1987-2010 (USFWS et al. 2010). Of guard dogs killed in the U.S. by wolves 61% have been Great Pyrenees. The killing of these dogs was likely a result of being out-weighed and out-numbered by wolves (Bangs et al. 2005). Some U.S. producers are in search of larger, more aggressive, and more effective dog breeds that can fight off wolf packs (Urbigkit and Urbigkit 2010). Central Asian Ovcharkas, one of the oldest breeds, have been used by sheep and goat herding pastoralists for centuries. Other dog breeds from Europe and Central Asia that show promise include the Transmontano Mastiff from Portugal, Turkish Kangal, and the Karakachan from Bulgaria. The Karakachan breeding program was started in Bulgaria in 1996 and has resulted in a breed of LPDs that work in teams to actively chase and harass wolves (Sedefchev and Sedefchev 2009). By placing LPDs with herders, Bulgarian herders have witnessed an 80% decrease in predator related losses in an area with some of the highest densities of bears and wolves in Europe (Urbigkit and Urbigkit 2010). Three to five LPDs working together, regardless of breed, has been the most effective combination for deterring the advances of a pack of wolves on flocks of sheep numbering approximately 1000 (Andelt 2004). A drawback of searching for a more aggressive guard dog raises concerns about conflicts with humans and wildlife on multiple use public land in the US. A guard dog's natural instinct to attack requires that individuals that exhibit aggressiveness towards humans be killed immediately (Urbigkit and Urbigkit 2010).

Effectiveness

From the perspective of a behavioral ecologist, dogs and other guard animals can be thought of as behavior-contingent, multisensory disruptive stimulus producers (Green and Woodruff 1988, Meadows and Knowlton 2000, Shivik 2006). Barking and chasing can be assumed to be disruptive stimuli, while biting attacking and fighting would result in aversion through competitive occupancy of the pasture. Effective LPDs can be relied upon to provide reactive and random service for producers that are trying to combat chronic depredation attempts. An observant and effective LPD will produce an aversive stimulus every time a predator approaches a pasture with livestock (Shivik 2006).

Colorado producers that employed LPDs reported losing less sheep to all causes than producers that did not have LPDs (Andelt 1999). While these results seem promising, a number of factors were not controlled for in this producer interview based report (Andelt 1999). A predictive model of LPD effectiveness based on field observations in the Mercantour region of France indicated that when LPDs are employed in conjunction with night penning of sheep they could control up to 94% of losses to wolves (Espuno et al. 2004). Similar success has been reported in central Idaho where the Lava Lake Lamb and Wool Ranch has employed a combination of LPDs, night penning, and shepherds to deter wolves from preying on their livestock (personal interview, Mike Leahy). LPDs carry an additional risk though, 10% of guard dogs eventually harass or kill the livestock that they are tasked with protecting (Green et al. 1984). Guard dogs should be considered an additional tool within a grazing operation and not a panacea to halt depredation by carnivores. A majority of data that determines the effectiveness of guard dogs has been collected through producer interviews and mail in self report surveys. This approach to data collection makes it difficult to separate observer bias from individual dog effectiveness and or training.

Training, Rearing and Cost

Livestock herding dogs are considered intelligent and responsive to human commands; on the contrary guarding dogs can be "hard headed" and independent without being aggressive towards the animals that they are meant to protect (Green and Woodruff 1999). Guard dog research has been primarily conducted in two locations, Hampshire College's New England Farm Center (NEFC) in Amherst, MA, and the U.S. Sheep Experiment Station (USSES), a facility operated by the USDA Agricultural Research Service, Dubois, ID. Both facilities report slight behavioral differences between various breeds and indicate that training and rearing creates the greatest difference in efficacy (Coppinger et al. 1988; Green and Woodruff 1999). Navajo herders have used livestock guarding dogs for several centuries in the southwestern U.S. to protect their livestock. Navajo dogs are not chosen from a long line of LPD specific breeds but rather chosen for desirable guarding and anti-predator traits; chosen dogs are then trained to deter predators from livestock. Navajo livestock protection dogs may have been influenced by Spanish colonizers that shared this sheep husbandry tool with the Navajo indicating that guard dog use is often linked to necessity when grazing in areas that contain predator populations (Black and Green 1984). Black and Green (1984) also indicated that LPDs occasionally will harass other wildlife that is located in or adjacent to pastures with livestock.

Proper socialization and training of a guard dog requires that it be placed with sheep or other livestock in a confining pen at the age of seven to eight weeks. This training period causes the pup to associate with sheep and form a loyalty bond (Andelt 2004). Undesirable traits should be corrected at this time including; livestock ear biting, aggressiveness towards humans or livestock, plucking wool, and running away from the sheep (Green and Woodruff 1999). One LPD can be relied upon to cover several hundred acres that contains a couple of hundred sheep, though this is dependent upon terrain features, operation factors, herd makeup, and individual dog characteristics (Green and Woodruff 1999). Producer reported observations suggest that LPD presence may act as an aversive stimulus tool that causes predators and ungulates to modify their behavior (Andelt 2004). This results in wildlife shifting their spatial use over time due to the presence of a perceived threat present with the livestock (Gehring et al 2010).

One Great Pyrenees pup can cost between $350-450 with average annual expenses of approximately $286 including; feed, veterinary bills, etc (Green and Woodruff 1999). Most LPDs can be permanently placed with livestock at 18 months; most dogs can be relied upon to serve the producer for approximately 8 years. When LPDs are employed in addition to night penning, herder presence, carcass removal, and mechanical scare devices; predation of sheep by carnivores has been significantly reduced (Espuno et al. 2004). Replacement of injured or killed LPDs necessitates that the livestock producer continually prepare for lethal encounter between predators and LPDs, this 18 month lag time includes pup rearing, training, and deployment with the flock.

Limitations

Despite the success that sheep operations have reported with LPDs, there are several limitations that should be considered when employing guard dogs. Sheep and goats are herd forming animals, which makes the use of a guard dogs more effective than with cattle that may have individuals that roam independently of the rest of the herd. Well trained and loyal LPDs will instinctively protect their herd from any approaching threats, this included a mountain biker that was savagely attacked in 2009 by two Great

Pyrenees that were protecting sheep on a public grazing allotment in Colorado (Shivik 2006; Riccardi 2009). LPDs are not pets but rather working dogs that are considered to be full time members of the flock, producers report that over socialized guard dogs lose some of their attentiveness to livestock (Andelt 2004). When LPDs are incorporated into the overall management of sheep operations it may require changes such as grazing sheep in smaller pasture arrangements, separating or grouping sheep, changing fence design and configuration, or altering the schedule of when a flock is checked (Green and Woodruff 1999).

Alternative Livestock Protection Animals

Llamas and donkeys have both exhibited guarding and anti predator characteristics. This observation has led producers to incorporate llamas and donkeys into their grazing systems to assist with protection services for livestock (Wilbanks 1995). The training and socialization period for llamas and donkeys is similar to dogs, but these animals do not need to be grafted to a herd at an early age like LPDs. They are most often utilized in conjunction with small pastures and are not often found on large open-range grazing allotments. Most of the evidence of their efficacy is anecdotal and observational in nature with no empirically based studies that quantify their usefulness to livestock producers. The initial cost of a llama is significantly higher ($700-$800) than dogs, and donkeys are lower at $75-$150 each, while the yearly food and care costs can be much lower for llamas and donkeys averaging about $70 annually (Wilbanks 1995). These costs are based on 1995 figures and could be significantly different especially in areas that would require supplemental feeding over the winter months. Llamas and donkeys live longer and are less susceptible to predation by wolves, though there have been twenty five confirmed depredation of domestic llamas by wolves in the NRM between 1987 and 2009 (Bangs and Shivik 2001, USFWS Interagency Report 2009).

Conclusion

My review of guarding and protection animals indicates that producers that employ the services of LPDs can experience a reduction in wolf related depredations (Andelt 1992, Espuno et al. 2004, Gehring et al. 2010). Highly structured grazing operations are more likely to realize an ameliorative effect from the use of a variety of non-lethal conflict mitigation tools (Shivik 2006). LPD breed type does not appear to determine effectiveness as much as the individual dog's natural instinct to protect (Green and Woodruff 1988). More aggressive breeds are currently in use in Europe, the risk of injury to humans and other wildlife needs to be considered by society if producers propose to employ more aggressive breeds on multiple use public lands in the US (Urbigkit and Urbigkit 2010). Livestock protection animals have been traditionally used in conjunction with herd forming animals such as sheep and goats, cattle do not exhibit the same herding tendencies which would decrease the effectiveness of LPD's placed with cattle. In Colorado, 84% of sheep producers that employed LPDs rated their LPDs as excellent or good at reducing predation of livestock by a variety of predators (Andelt and Hopper 2000). While this study does not consider wolves, NRM sheep producers have reported measurable success when utilizing the services of guard dogs in wolf country. The psychological benefits of LPD's provide peace of mind to producers and present the opportunity to more effectively detect predator presence (Marker et al. 2005). While producer reported data suggests successful implementation of guard dogs, empirical evidence is lacking. Nevertheless, a majority of U.S. sheep producers employ some combination of herders, guard dogs, and night penning with measurable success. In most cases LPDs represent a cost effective way to reduce the impact of predators on herds of livestock.

Fladry

Fladry is a visual deterrent designed to deter wolves from entering specified areas. Fladry was originally used to force wolves into a bottleneck enclosure where they could be live captured or killed (Okarma and Jedrzejewski 1997). Fladry first came into use as a wildlife management tool in 1997 when researchers demonstrated that it could confine wolves in a pen overnight so that they could be chemically immobilized, collared, and safely released back into the wild (Okarma and Jedrzejewski 1997). Wolves exhibit a fright or startle response to this visual barrier which disrupts their path of travel causing them to avoid areas that are surrounded by fladry (Musiani and Visalberghi 2001). Fladry consists of brightly colored pieces of cloth placed at consistent intervals along a rope or wire that is suspended between posts so that the flags hang nearly to the ground creating a visual barrier. Fladry flags are most often red, but gray and orange flags have shown similar effectiveness (Musiani and Visalberghi 2001).

Wolf managers collaborating with livestock producers have adapted fladry into a tool for deterring wolves from pastures with livestock; thus, reducing the frequency of encounter between wolves and livestock. Musiani and Visalberghi (2001) demonstrated that food deprived captive wolves will avoid a food source that is surrounded by a fladry barrier. They found that the optimal configuration included 50 cm X 10 cm red (gray and orange seemed to have the same effect) flags suspended from a rope at an interval of no more than 50 cm apart with an above ground height between 25 and 75 cm. The wolves tested and eventually crossed the barrier indicating that time may play a factor in how long the fladry is effective. Primary repellants are limited in their effectiveness due to habituation, the effectiveness of disruptive stimuli can be prolonged by randomizing stimuli and location or it must be sufficiently noxious to create long term changes in behavior (Shivik et al. 2003). Musiani and Visalberghi (2001) observed that captive wolves would bite at the fladry in an attempt to test the barrier and when the experiment was over the wolves crossed the boundary when they were pushed toward it by the researchers. While this study was specific to captive wolves and it established the optimal configuration of fladry, the researchers realized that field trials would be necessary to test efficacy in conflict situations. Musiani and Visalberghi (2001) hypothesized that wild wolves could be deterred from entering an area surrounded by fladry.

Musiani et al. (2003) conducted a study of fladry efficacy using both captive and wild wolves in Idaho, U.S. and Alberta, Canada. In the captive tests, they found that fladry was effective at stopping wolves from crossing a barrier for 28 hours in nine of eighteen trials. In field trials with wild wolves they found that wolves did not cross a fladry barrier that enclosed a carcass in a 100 m^2 area for 60 days on two different occasions. Further field trials in Alberta documented wolves approaching and not crossing a fladry barrier a minimum of 23 times in 60 days that surrounded a 25-ha pasture that contained cattle (Musiani et al. 2003). Cattle were killed by wolves in a nearby pasture that did not have a fladry barrier. Field trials in Idaho resulted in four radio-collared wolves crossing a fladry barrier and killing cattle on a fladry enclosed 400-ha ranch after 61 days of pasture treatment indicating that habituation does occur with time. This study indicated that fladry was effective for a limited amount of time in field situations, and wolves appeared to use alternative prey species when one potential prey item was protected by fladry (Musiani et al. 2003).

In 2004 and 2005, Nelson and Gehring (2010) tested fladry in a field based block design that included treatment and control pastures in areas with active wolf packs and coyotes in Michigan, U.S. They reported that the cost of establishing and maintaining fladry was $915/km ($1,473/mile) or $4,392/year on a 150-ha farm with a perimeter of 4.8 km (2.98 miles). The producer's annual depredation losses would have to exceed 37 lambs or 11 calves to equal the approximate costs of using fladry (Nelson and Gehring 2010). The researchers reported that there were two occasions when wolves crossed the fladry barriers. One instance occurred when calves had destroyed a portion of the barrier and the second occurred when a temporary fladry gate was not operational. In both situations, the fladry barrier had been previously breached and not repaired prior to the documented crossing. There were zero reported wolf depredations and eight confirmed coyote depredations on sheep during the two years of this study (Nelson and Gehring 2010).

Observations of wolves testing fladry by biting at the flags and the eventual habituation by wolves led to the development of electrified or "turbo fladry." Turbo fladry is similar in design to the optimal layout described by Musiani and Visalberghi (2001); except that the flags are attached to an electrified braided poly-wire that delivers a shock to a wolf's nose or mouth. This modification to traditional fladry created a primary and secondary repellant that was hypothesized to reduce the habituation of wolves to a non-injurious primary repellant (Lance et al. 2010). Secondary repellants condition animals by using aversive stimuli to elicit flight behavior initiated by discomfort, pain, or a negative experience thus preventing a particular behavior (Elliot and Covington 2001; Shivik et al. 2003; Shivik 2004; Lance et al. 2010). Lance et al. (2010) carried out a paired study design that analyzed the efficacy of electrified fladry on captive and wild wolves in areas of prior conflict with livestock. Lance et al. (2010) found that turbo fladry was the most effective barrier when compared with no visual barrier and traditional fladry. Field trials of turbo fladry have been plagued by low frequency of encounter rates making analysis of efficacy weak (Lance et al. 2010).

Lance et al. (2010) conducted a post treatment interview survey which indicated that fladry barriers provided peace of mind for the producers that received fladry treatments. Lance et al. (2010) also found that all producers were unwilling to install fladry if they incurred the entire cost of the treatment ($2,303/km ($3,846/mile), 31.8 person hours/km (53.1 person hours/mile) installed, and maintenance costs). This indicates that there is a psychological benefit to the producer and 83% of those surveyed would use fladry again in certain situations (Lance et al. 2010).

Traditional and turbo fladry have shown some promise in field and captive studies. It should be noted that habituation does occur with time. The initial cost of fladry is prohibitive, especially for large installations. Fladry as a long term deterrent should be coupled with other tools that can reduce the frequency of encounter between wolves and livestock in field situations. Maintenance of fladry is time consuming and should include random adjustments to location to provide optimal novel disruptive stimuli. The time commitment to maintain fladry and the monitoring effort required to determine efficacy could contribute to the perceived effectiveness of this tool. Human presence and scent was not considered as a deterrent factor in these fladry studies.

Husbandry Practices and Human Presence

Livestock producers will change their husbandry practices when they perceive that the change will increase productivity. Husbandry changes can result in increased herd health and ease of operation for the rancher thus reducing overhead variable costs such as feed expenditures, veterinary bills, and labor costs. Variable costs are often targeted by economists as the best way to respond to the fluctuating wholesale price received by producers for lamb, wool, and beef (Rashford 2010). However, Berger (2006) found that fluctuating hay prices, rising wages for livestock workers, and a drop in the wholesale price of lamb and wool had a greater impact on the long term viability of the sheep industry in the U.S. than did predation losses to coyotes.

As recently as 20 years ago, wolves were not present in the NRM and ranchers became complacent in their anti-predator husbandry practices. When wolves began to recolonize the NRM, livestock were considered a naïve prey base, therefore making them more susceptible to lethal wolf encounters (Berger et al. 2001). Yet wild naïve prey demonstrated the ability to develop a hypersensitivity to re-colonizing predators within one generation making them more vigilant and less susceptible to future predation attempts (Berger et al. 2001). The following review of husbandry practices is useful for producers that are searching for tools that might reduce their losses to wolves.

Managing Food Attractants

Analysis of grizzly bear and human conflicts from 1986-2001 along the East Front of the Rocky Mountains, Montana revealed factors that might predispose conflicts (Wilson et al. 2006). Spatial analysis of conflicts and habitat factors found that the presence of riparian vegetation and distances to spring, summer, and fall sheep or cattle pastures, calving and sheep lambing areas, unmanaged boneyards (livestock carcass disposal sites), and fenced and unfenced beehives were all associated with the likelihood of human-grizzly bear conflicts (Wilson et al. 2006). While this analysis of the proximity of attractants to human-grizzly bear conflict should not be assumed to predict the occurrence of wolf and livestock conflict, the predictive model established that collections of attractants concentrated in high quality wildlife habitat largely explain broad patterns of human-grizzly bear conflicts on private agricultural land in the study area (Wilson et al. 2006). Multiple predator systems could benefit from the control of attractants that decrease the frequency of encounter between all predators and humans or livestock. Fine scale analysis of unmanaged boneyards and lambing and calving areas represent a food attractant for grizzly bears and it could be assumed that wolves would frequent these areas putting adjacent livestock at risk of depredation attempts.

Several identifiable factors may form patterns that predispose livestock on some ranches and farms to higher rates of wolf depredation (Mech et al. 2000, Bradley and Pletscher 2005). Mech et al. (2000) compared farms with and without wolf depredation in Minnesota and found that farms that experienced chronic depredation were larger, had more cattle, and grazed cattle farther from human dwellings. Bradley and Pletscher (2005) examined wolf predation on cattle in Montana and Idaho and also found that larger pastures with more cattle located farther away from residences were more likely to experience wolf predation problems. Also, the presence of elk near pastures was strongly related to livestock depredation by wolves (Bradley and Pletscher 2005). Both studies also examined livestock husbandry factors that might contribute to depredation risk.

Analysis of wolf depredation sites concluded that improper carcass disposal might increase the risk of wolf depredation of one farm over another (Fritts 1982, Fritts et al. 1992). This claim was examined by Mech et al. (2000) whom concluded that there was not a strong connection between proper carcass disposal method and depredation occurrence. The researcher collected this data through self reporting interviews, and admitted that false reporting may have skewed the data after consulting with USDA-WS personnel that had responded to depredation on those farms (Mech et al. 2000). Due to the confounding results from the survey, the researcher concluded that the effect of proper carcass disposal remains open. Bradley and Pletscher (2005) examined husbandry practice differences on farms in Montana and Idaho and determined that there was no discernible relationship between depredation occurrence and carcass disposal, calving locations, calving times, breed of cattle, or the distance that cattle were grazed from the forest edge. Proper carcass disposal was not found to be correlated to depredation occurrence based on rancher reporting. The researchers recommended that the question of carcass disposal would best be addressed with fine scale analysis of carcass presence or absence near the time of a confirmed depredation by wolves and if the wolves had fed on the carcasses (Bradley and Pletscher 2005). Both of these studies concluded that proper carcass disposal was still an open question and that fine scale analysis might be able to determine the importance of proper carcass disposal.

Conflicts with grizzly bears are associated in space with high quality food resources (Wilson et al. 2006). Chaves and Gese (2006) found a similar pattern for radio collared wolves in Minnesota that frequented carcass disposal sites and often traveled through pastures with cattle to access the sites. When the farmers were informed of this attractant site they removed the carcasses and the wolves ceased to frequent that area (Chavez and Gese 2006). Any attempts to control attractant sources through the proper removal of carcasses or by constructing predator exclusion fencing might decrease the risk of raising livestock in areas that are adjacent to prime predator habitat. Proper carcass disposal might be a way to decrease the frequency of encounter between wolves and livestock thus reducing the risk of conflict. Future analysis of wolf movement patterns should focus on the proximity and percent use of areas that contain unsecured livestock carcasses, which represent a food source that might attract wolves.

Detecting Livestock Vulnerability

Livestock with a smaller body size are vulnerable to a wider variety of predators (Fritts 1982) indicating that calves and sheep are more susceptible to depredation than adult cattle (Fritts et al. 1992; Oakleaf et al. 2003). Producers that practice shed lambing, i.e. keeping ewes inside a shed when they are giving birth to lambs, can reduce lamb losses due to predators and other climate related stresses (Shivik 2004). Calving adjacent to human habitations allow for constant vigilance, while producers that calve far from buildings expose their livestock to a greater risk of predation (Shivik 2004). Producers that erect predator electric exclusion fencing surrounding their calving and lambing grounds may significantly reduce their risk of depredation from a variety of predators by providing a safe haven for neonate livestock (Wilson, unpublished data). Sheep producers in the U.S. and France that employ herders, practice night penning, and utilize guard dogs also report lower rates of predator and livestock encounters (Espuno et al. 2004, Andelt 2004). Ogada et al. (2003) found that herders in Africa who constructed bomas for night penning, utilized guard dogs, and increased human activity around grazing livestock had the lowest rates of depredation. In a follow up study Woodroffe et al. (2007) quantified the various aspects of Ogada's work reporting that the presence of just one domestic dog and a herder during the day decreased the herd's risk of attack by 63%. When they considered boma construction they found that each additional door on the boma wall increased the chance of predator attack by 40% (Woodroffe et al. 2007). This African example indicates that a long uninterrupted history of existence with predators has led to the development and use of low tech livestock husbandry practices that reduce predation levels. These techniques have allowed carnivores and traditional pastoralists to coexist with less loss than commercial ranch operations who often do not employ predator conflict mitigation tools (Treves and Naughton-Treves 2005). Some sheep producers in Idaho, U.S. are beginning to utilize fladry and turbo fladry as a temporary night penning to deter predators in open range situations (Leahy, p. c.). This tool has proven particularly effective when used in conjunction with herders, LPDs, and RAG boxes. Producers that practice concentrated night penning of livestock should be aware of the potential for range resource damage and the possibility of disease transmission between livestock (Shivik 2004).

Producers throughout the world have responded to predation events by increasing their vigilance when livestock at most at risk of depredation. Some cultures continue to practice these techniques with recognizable success. Prior to the recovery of wolves in the NRM, livestock producers did not have to worry about wolves as a predator. Implementation of husbandry techniques that focus on increasing vigilance when livestock are at risk of depredation will significantly decrease risk. NRM livestock producers can learn from the efforts of cultures that have had an uninterrupted history of co-existence with predators.

Human Presence

Human presence is a significant factor in reducing predation. When wildlife managers in Minnesota attempted to trap depredating wolves, regardless of the result, the trapping effort reduced future livestock depredations indicating that human activity near depredation sites might deter future depredation attempts (Harper et al. 2008). In Sweden, depredated farms are 55 times as likely to experience repeat depredation by carnivores in the following 12 months as other farms in the area (Karlsson and Johansson 2010). Repeat attacks by wolves occurred within 5 weeks in 60% of the cases and the main mechanism implicated in wolf return was the availability of livestock carcasses (Karlsson and Johansson 2010). Reactive use of conflict mitigation tools in the first five weeks following a depredation reduced the chance of repeat depredation (Karlsson and Johansson 2010). As discussed earlier in this review, aversive stimuli that reinforce a fear of humans in wolves might make consistent human presence in livestock herds effective at reducing future depredations.

Due to the labor cost of continual monitoring of livestock, it would be useful for ranchers to be able to predict the seasonal occurrence of depredations. This information would allow ranchers to deploy limited funds at times of highest risk. An analysis of wolf depredation history of livestock in Montana, Idaho, and Wyoming between 1987 and 2003 revealed seasonal increases in depredation events (Musiani et al. 2005). The study indicated that depredations were most prevalent from March-October with a spike in August, the November—February season had an overall lower number of depredations (Musiani et al. 2005). The data suggested that depredation coincided with the grazing season May—October and that the first spike in depredations coincided with the beginning of seasonal calving (March—April) (Musiani et al. 2005). The regional nature of this data set allowed for generalizations to be made, a fine scale analysis of depredation seasonality at the watershed level could provide ranchers with a more accurate indicator of risk. It should be noted that neonate livestock are vulnerable to predation and NRM grazing seasons coincide with decreased herd supervision rates.

Other impacts of predators on prey species, especially livestock, are of interest to wildlife and livestock managers. Most prey species choose high quality forage based on the risk of obtaining it in light of predator presence. Wild ungulates such as elk will preferentially choose high quality forage when wolves are absent, but will choose forest cover habitat (security) when wolves are present (Muhly et al. 2010). Some propose that prey specie's balance between cover and food is mediated by the presence or absence of a predator (Muhly et al. 2010, Laporte et al. 2010). This response has been termed anti-predatory behavior, which some propose has been attenuated in cattle through artificial selection (Muhly et al. 2010). Muhly et al. (2010) tested this theory in cattle with a resource selection function that utilized spatial data from cattle and wolves that were located in the same pasture in southwest Alberta, Canada. The results indicated that cattle responded to wolf presence by avoiding high-quality-food habitat and selecting areas closer to roads and trails where people likely provided security. These effects began only after wolves had left the area indicating a lag effect (Muhly et al. 2010). The results indicate that both elk and cattle respond to wolf presence by avoiding high quality forage habitat (risky) and choose for security habitat (safe) (Muhly et al. 2010). Laporte et al. (2010) determined that livestock anti-predator response had not been attenuated in cattle through artificial selection, but rather that cattle associated humans and human development as security habitat. This result also indicates that cattle, by choosing lower quality forage, could experience a decrease in productivity when wolves are present (Laporte et al. 2010). The implications of wolf mediated non-consumptive effects necessitate that depredation compensation funds and society consider reimbursing ranchers for loss of productivity when wolves are present on grazing landscapes (Laporte et al. 2010). According to this conclusion, human presence in pastures where livestock and wolves interact should promote optimal utilization of high quality rangeland resource by mediating anti-predator response and moving cattle to areas of optimal range condition.

Conversations with livestock producers in the field revealed several other factors that could possibly dictate increased conflict between wolves and livestock. This literature review did not find evidence to support the assumption that factors such as livestock breed, color, health, physical deformities or livestock herd makeup had ever been empirically considered. These factors are anecdotal in nature and they will be difficult to prove until a more robust data set has been gathered that can properly asses the factors that might dictate predator vulnerability of individual livestock.

Conclusion

Livestock husbandry when viewed through a lens of reducing conflict between wolves and livestock suggests that human presence and activity has the potential for deterring future depredations. Changes in husbandry practices could decrease depredation risk. However, conflict between wolves and livestock is inevitable when they interact on public and private land in the NRM. Collaborative approaches to predator management could foster positive relationships between agency wolf managers, livestock producers, and non-government organization partners (Treves et al. 2009). A combination of husbandry practices, properly managing food attractants, human presence, and the timing of mitigation tools can reduce the chance of repeat lethal encounters between predators and livestock (Ogada et al. 2003, Andelt 2004, Shivik 2004, Wilson et al. 2006, Treves et al. 2009, Karlsson and Johansson 2010).

Implementing a combination of the reviewed techniques for reducing conflicts between wolves and livestock is the most effective strategy to reduce losses. The various tools are more or less effective for each individual rancher depending upon unique operation factors. Each tool is additive and equates to increased human presence in livestock herds. This fact led to the development of the following program that is focused on significantly increasing herd monitoring and presence in areas that have an elevated level of wolf and livestock interaction.

SECTION 3. Blackfoot Wolf and Cattle Monitoring Program

Introduction

The Blackfoot Challenge, a watershed group, has been actively involved in collaborative conservation since 1993. Efforts by the Blackfoot Challenge beginning in 2002 to address grizzly bear expansion onto private agricultural lands resulted in the formation of the Blackfoot Challenge's Wildlife Committee. The committee, made up of ranchers, landowners, researchers, NGOs, and federal and state agency personnel, was aware of wolf re-colonization in many portions of the state and began preparing for the presence of wolves in the mid-2000s. For example, more than 50,000 linear feet of permanent electrified fencing had been built around calving areas on more than a dozen ranches to deter grizzly bears. These fences were also designed to deter wolves in preparation for their arrival several years later. By 2008, the Wildlife Committee had instituted the first pilot "Range Rider" or livestock monitoring effort. By 2009, the Wildlife Committee decided to expand the livestock and wolf monitoring effort and subsequently hired a contracted individual to assist livestock producers to increase livestock and wolf monitoring. The program was based on the assumption that increasing human presence and livestock herd supervision rates might help decrease the frequency of encounter between wolves and cattle and reduce livestock depredations. The following section illustrates the history, assumptions, and results to date of the efforts in the Blackfoot Watershed to reduce the conflicts between wolves and livestock.

Approach

The Blackfoot Challenge has been actively working to reduce the risk of livestock losses to wolves in the Blackfoot watershed since 2007. In addition to livestock carcass removal and electric fencing of calving areas, the Blackfoot Challenge has hired several seasonal range riders to help monitor wolf and livestock activity and to provide non-lethal tools to help reduce the chances of livestock depredations by wolves. These coordinated efforts were a result of a close partnership with MT Fish, Wildlife and Parks and the U.S. Fish and Wildlife Service. The following summary reviews the 2009 and

2010 seasons. Additionally, I provide a summary of overall range rider effort in the study area.

2009 Range Rider Field Season

The 2009 Blackfoot Range Rider season focused on developing relationships with ranchers, monitoring wolf activity, establishing working relationships with state and federal agency partners, and developing protocol for future monitoring efforts.

Field Season Statistics:

- Completed 7 month field season to monitor livestock and 4 wolf packs
- Successfully monitored 850- 1000 cow/calf pairs per week across 45,000 acres
- Documented 18 rider/wolf encounters for the period 4/1/09-9/30/09
- Averaged 5.5 days/week of herd supervision (vigilance/presence) for the period 4/1/09-9/30/09
- 2 confirmed calf (orphaned) losses (mid-Sept.) to wolves for the period 4/1/09-9/30/09
- Deployed fladry (visual fencing deterrent) after two confirmed calf depredations as a means to reduce risk of future depredations. Fladry was left in place for approximately 35 days and no subsequent depredations were reported.

Social Tolerance / Communication Statistics:

- Successfully built trust and credibility with 8-10 ranchers whose herds were at greatest risk and communicated regularly with another 40-50 landowners and ranchers who were at moderate risk of depredations by wolves throughout the project area.
- Made 200-250 telephone and e-mail contacts regularly from 4/1/09 – 9/30/09
- Produced 16 regular wolf and livestock activity reports for community distribution
- Maintained weekly contact with MT Fish, Wildlife and Parks and Blackfoot Challenge

2010 Range Rider Field Season

The 2010 range rider season in the Blackfoot Watershed focused on increasing human presence in livestock herds that were adjacent to concentrations of wolf activity based on observations from the previous year. This was accomplished through the addition of two paid assistants and increased effort on the part of livestock producers grazing in those areas. This was the second official year of livestock and wolf monitoring efforts carried out by the Blackfoot Challenge.

Cattle monitoring efforts also helped producers track overall herd health. In 2010 livestock producers removed three calves, two cows, and two bulls from grazing allotments when they were found to have injuries or health conditions that we assumed made them at higher risk of depredation. We also noticed that cattle grazing in wet or sub-irrigated grazing allotments had a higher risk of foot rot and injury especially in areas that had been previously logged or had excessive blown down timber. Immunity boosters and hoof health supplements can be added to mineral blocks, thus supporting cumulative herd health by reducing debilitating injuries and subsequent susceptibility to predation attempts.

We focused our monitoring on the Ovando Mountain and Arrastra Creek Packs. The Ovando Mountain Pack had two radio collars placed in the pack in 2010, facilitating intensive monitoring and active hazing which included the use of less than lethal munitions, increased human presence, and vehicle noise to deter wolves away from cattle. Monitoring efforts resulted in locating members of this pack within 0.5 miles (0.8km) of cattle on 51 of 74 monitoring days. Members of this pack of wolves were sighted in a pasture with cattle on eleven occasions. One calf depredation occurred on the 89th day of grazing in that pasture. Subsequently three individuals were lethally removal from this pack and the cattle were moved out of this pasture. There were no more reported incidents between cattle and wolves in this area through the remainder of the fall grazing season. The Arrastra Creek pack had no collared individuals, making pack location monitoring difficult. One depredation early in the grazing season resulted in the removal of one adult male wolf from this pack. Intensive cattle monitoring in this area as well as trapping activity by USDA's Wildlife Service agents and Montana Department of Fish, Wildlife and Parks resulted in a significant increase in human presence in the core use area of this pack, which overlaps with summer grazing allotments on public and private lands. No other conflicts with cattle were detected in this area for the remainder of the 2010 grazing season.

2010 Field Season Statistics:

- Completed 6 month field season to monitor livestock and 4 wolf packs
- Successfully monitored 650-800 cow/calf pairs per week across 45,000 acres
- Documented 22 rider/wolf encounters for the season (5/1/10-10/31/10).
- Radio telemetry monitoring of Ovando Mt. Pack documented presence of wolves within 0.80 km (0.5 mi) of livestock on 51 of 74 monitoring days during grazing season on BCCA.
- Range rider, two assistants, and 5 ranchers collectively averaged 100 hours of 168 possible hours in vigilance/presence for livestock herd monitoring per week on 5 herds for the season.
- 2 cows, 3 calves, and 2 bulls that had health issues/injuries were removed from high risk areas where cattle and wolves were both present.
- 4 confirmed livestock losses (2 calves; 1 cow; 1 horse) during the season
- 8 wolves lethally removed for livestock depredations during the grazing season
- Deployed fladry on two ranches for approximately 30 days as a preventative tool.

Social Tolerance / Communication Statistics:

- Successfully maintained trust and credibility with 8 ranchers from the previous field season and cultivated relationships with two additional ranchers whose herds were at greatest risk.
- Maintained regular communication with an additional 40-50 landowners and ranchers who were at moderate risk of depredations by wolves throughout the project area.
- Maintained regular communication through list-serve and Blackfoot Challenge website with 121 people.
- Maintained regular email and phone contact with producers and community members from 5/1/10 – 10/31/10

- Produced 10 bi-weekly *Wolf Activity Reports*, which were distributed to community and project partners
- Maintained weekly contact with MT Fish, Wildlife and Parks and partners.
- Made 6 public presentations on wolf issues to approximately 140 people.

Results:

Wolf Pack Establishment in the Blackfoot 2006-2008

Prior to the establishment of the official Range Rider project which commenced in 2009, wolf activity was first documented in the defined project area in late 2006. By early 2007, MT Department of Fish, Wildlife and Parks officially confirmed the Elevation Mountain pack, which consisted of 7 known individuals.

By mid-April 2008, there were 2 confirmed livestock depredations attributed to the Elevation Mountain pack in the project area and during early June, two additional depredations occurred by the Elevation Mountain pack. Subsequently there was an incremental, lethal control action executed by Wildlife Services (USDA) that resulted in 3 wolves being lethally removed from this pack. Despite monitoring efforts an additional calf was injured by this pack in 2009, resulting in two additional wolf removals. By May of 2010 another calf was killed and USDA-WS agents lethally removed the remaining three wolves from the Elevation Mountain pack. It should be noted that the ranch on which several calf depredations occurred has a late calving season beginning in May. Additionally this ranch has an "open" pasturing approach calving where cow/calf pairs are widely dispersed across sagebrush pastures where a resident elk herd calves, thereby increasing predation risk. Throughout the time period of 2006-2010 wolves continued to colonize in the Blackfoot watershed resulting in population growth.

2009

Livestock and wolf monitoring begins April 1, 2009. Four additional wolf packs are documented in the project area (Ovando Mountain, Arrastra Creek, Belmont, and Lander's Fork packs) and several wolves are documented using the Blackfoot Clearwater Game Range ("Game Range Wolves") area in early 2010 bringing the total number of wolves in the general Blackfoot Valley to approximately 25-35 animals including pups. Two orphaned calves are confirmed as losses to wolves (likely the Ovando Mountain pack) in mid-September, 2009. The removal of two wolves was authorized by MT Fish Wildlife and Parks, but USDA-WS agents were unable to capture and remove any wolves from this area. Three coyotes were captured and lethally removed while traps were set for wolves that might return to the depredation site.

2010

As summarized above, repeated livestock depredations by the Elevation Mountain pack resulted in full pack removal by May, 2010. One individual from the Elevation Mountain pack was killed by a livestock producer in protection of private property through the 10j provision of the ESA, when it was observed chasing cow-calf pairs. The remaining two individuals from this pack were lethally removed by USDA-WS agents two days later in an adjacent pasture. Ten days later within the Elevation Mountain pack territory, the tracks of two wolves were observed in a pasture where a horse had been chased into a fence and injured beyond repair. This confirmed wolf depredation resulted in the lethal removal of one wolf that was not at that time associated with any of the defined packs in the Blackfoot Valley. Additionally, one cow was confirmed killed by wolves (Arrastra Creek Pack) and one wolf was removed; no additional livestock losses were reported in this pack's territory. Despite intensive monitoring of the Ovando Mt. pack and consistent livestock supervision on the BCCA, one calf depredation occurred one day prior to all cattle being removed from those pastures. Subsequently, three adult (non-collared) wolves were lethally removed by USDA Wildlife Service agents.

Pre-Range Rider Baseline 2007-2008:

4 confirmed calf losses

1 confirmed wolf pack (7 individuals)

4 wolves removed

Range Rider Outcomes 2009:

2 confirmed calf losses

3 confirmed wolf packs (est. 25-35 animals including pups)

2 wolves removed

Range Rider Outcomes 2010:

4 confirmed livestock losses (2 calves, 1 cow, 1 horse)

5 confirmed wolf packs (est. 34 animals including pups)

8 wolves removed

SECTION 4. Discussion

The use of intensive herd monitoring or range riding is an important tool that may reduce the risk of livestock depredation by wolves in the Blackfoot Watershed. However, the beneficial effects observed in the 2009 field season should be tempered by the fact that subsequent livestock losses to wolves occurred in 2010 despite concerted herd supervision of cattle that grazed in active wolf territory. Earlier removal of livestock from those pastures may help reduce future livestock losses to wolves. Our herd supervision efforts may have helped prevent potential losses to wolves when injured or sick individuals were removed from high risk areas. This occurred 7 times during the field season.

Regular monitoring of wolves and developing extensive communication networks in the project area would not have been possible without the help of ranchers, residents, and our agency partners. Cultivating trust within the ranching community is essential for documenting wolf numbers/packs, understanding wolf pack behavior, documenting conflicts, and ultimately for developing the willingness by landowners to engage in proactive efforts that reduce livestock depredation risk to both grizzly bears and wolves. Montana Fish Wildlife and Parks wolf specialists have limited amounts of time to spend in the Blackfoot Watershed. Our efforts as a proactive liaison between private land owners and public officials assisted with access issues, wolf monitoring, and education efforts with this rapidly changing and dynamic wildlife management issue. Additionally, this relationship resulted in an efficient local wolf management program that included both non-lethal and lethal tools for controlling livestock depredations.

The following quotes were heard while interacting with the ranching community in the Blackfoot watershed:

--"This program has helped us to speed up our learning process on how to react to wolves so that we can make good decisions in the future"….DM

--“It gives me peace of mind to know that we have someone up there in the woods watching our cows when we are busy at home with haying or other ranch chores”….BR

--“Sure go ahead and watch the cows for me, I wish I had time to goof off in the woods all day”….GC

--“I didn’t ever like going down into that brush pile along the river to check cows anyway, but sure go ahead and let me know if you find anything dead”….WS

--“Can’t we just use that radio receiver thing and go get us some wolves”….RB

--“Well I guess if the wolves don’t get ya, maybe the grizzlies will”….KK

--“With all the wolf activity, I kept expecting a lethal interaction, but it never happened”…LB

I am hopeful that the combination of livestock carcass removal, electric fences that serve as safe havens for livestock from bears and wolves, deployment of fladry in discreet locations, and our range rider project in the Blackfoot Valley are having a cumulative, positive effect that helps people and wolves coexist in an agricultural landscape. By increasing human presence in livestock herds in the Blackfoot Valley; I have demonstrated that wolves can be deterred from pastures with cattle. Maintaining and recording a yearly account of wolf and livestock interaction in the Blackfoot watershed will allow future managers to change husbandry practices that predispose conflicts with predators. This is a key component based on the fact that cattle currently spend a significant amount of time grazing in desirable wildlife habitat that supports both wild ungulates and a variety of predators. Yet, we need to maintain objective conversations, based in fact, to promote a socially acceptable and sustainable wolf management program in the Blackfoot watershed. In a landscape that values both rural livelihoods and viable wildlife populations, we will continue to witness encounters between predators and livestock. Whether we view these encounters as conflicts is for us to decide.

Recommendations

Negotiating the complex array of biological and social factors presented by implementing a wolf and cattle monitoring program in the Blackfoot Watershed has been challenging. While the preceding case study attempted to be exhaustive, it would be inappropriate to assume that I encountered the array of lessons to be learned by working at this level with a rural community in ranching landscapes of the Western US. The sheer volume of conservation ground work completed by the Blackfoot Challenge prior to the start of this project paved the way to success by preparing the local people for a social and biological challenge of this magnitude. While I have explored a variety of topics, this only represents a brushstroke in the complex picture that represents social tolerance and acceptance of predators in a livestock production focused landscape.

Several of the key components to a successful program include; strong working relationships with agency personnel, supportive working relationship with local producers, strong local support from non-producers that represent both hunters and conservation minded citizens, thorough knowledge of biological field monitoring protocol, and a desire to work long hours in pursuit of coexistence with predators across the rural and wildland interface. While this level of effort and commitment to working together may not be possible in every watershed in the NRM, it should be noted that most rural dwellers in the NRM have a very strong connection to the open landscapes of the western U.S. With that in mind, there is a lot of good work to be done, and Wendell Berry summed it up nicely when he wrote (Berry 2001):

"The most tragic conflict in the history of conservation is that between environmentalists and the farmers and ranchers. It is tragic because it is unnecessary. There is no irresolvable conflict here, but the conflict that exists can be resolved only on the basis of a common understanding of good practice. Here again we need to study and foster working models: farms and ranches that are knowledgeably striving to bring economic practice into line with ecological reality, and local food economies in which consumers conscientiously support the best land stewardship."

I learned many lessons and recorded a variety of patterns about wolf activity in the Blackfoot watershed. A consistent field record of wolf and livestock interaction will allow ranchers, watershed group personnel, and wildlife agency biologists to strategize as to how best to proceed with future efforts to decrease the risk of negative encounters between wolves and livestock. An annual review of the range rider's effort and current wolf pack distribution will help with planning for the next year's grazing season.

The Blackfoot Watershed represents a unique mixture of people living as a community in an intact ecosystem. This fact allows this community to continue to learn from its mistakes by listening to neighbors. This project would not have been possible without the support of Blackfoot Valley community members, land management agency personnel, and the generous support of the communities outside of our watershed boundaries. Future research needs include; a spatial account of wolf and cattle interaction, a review of historic wolf and cattle conflicts to determine if defined factors predispose a pattern in conflicts, a review of range rider treatment and control packs to determine if range riding decreases conflict, and an interview of community members to determine what aspects of the range rider program are most beneficial for developing support of wolf management in the Blackfoot watershed.

A literature review and case study of non-lethal conflict mitigation tools provides strong support for the following recommendations when considering efficacy studies of wolf conflict mitigation tools and strategies for building social tolerance of wolves:

1. Implement adaptive management systems where inputs and decisions are integrated with monitoring at various spatial and temporal scales. Management decisions should be updated on the basis of responses to previous actions based upon the specific management strategy that wolf conflicts with livestock are currently managed under. This approach would be particularly useful in areas that have varying densities of livestock and where producer commitment to conflict mitigation varies from one to the next. This would support local management of wolves and focus on implementing conflict mitigation tools in areas where producers show an interest in co-existing with wildlife in general.

2. The expense of implementing conflict mitigation tools is cost prohibitive for most livestock producers. Developing working relationships with conservation organizations that can provide the monetary support for implementation and can lead to positive collaborative partnerships between stakeholders groups that hold widely different views on predator management. Fostering these relationships will require the support of wildlife management agencies in practice and policy through their wildlife management plans. Lethal control of wolves that come into conflict with livestock undermines the monetary investment and time commitment that producers and conservation organizations have expended.

3. The North American Model of Wildlife Management requires that wildlife management plans include a scientific analysis of all management decisions. While this is an ideal circumstance, social science should also play a part in these

decisions, which will allow the full spectrum of values to be represented when wildlife policy is crafted. Social tolerance of wolves across the NRM will be dependent upon stakeholder groups accepting both lethal and nonlethal methods of controlling wolf populations. This reality will require that social science factors be considered when local wolf densities are augmented in a way that reduces conflicts with livestock.

4. Implementation of conflict mitigation tools and field based education efforts significantly increases the local knowledge of wolves and their predation patterns. This effort generally decreases the negative emotional reaction that livestock producers have to wolves at an individual level. Yet a traditional negative emotional response to wolf presence prevails when livestock producers interact socially in ranching industry associated groups.

5. Leadership from within the ranching community, for implementation of non-lethal wolf conflict mitigation tools is lacking, especially when ranchers are asked to step up as leaders in front of their peers. This is often based in fear that the leader will lose the support of traditional ranchers, whom are often unwilling to make management changes regardless of the benefit to their livestock production system. Market driven approaches that build support for proactive efforts could reward those producers by developing a niche market that is based on their specific stewardship practices.

6. A proactive local liaison that interacts with the various wildlife agencies and represents the local ranching community significantly increases the efficiency of both lethal and non-lethal management of wolves. This person must possess an understanding of both cultures. This is an invaluable person for both groups to support. Collaborative conservation efforts should seriously consider this type of position when faced with any of the value laden natural resource issues that often turn into locally paralyzing conflicts.

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