Non-Lethal and Lethal Tools to Manage Wolf-Livestock Conflict in the Northwestern United States

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ABSTRACT: Gray wolf populations were eliminated from the northern Rocky Mountains of the western United States by 1930, largely because of conflicts with livestock. The wolf population is now biologically recovered and over 1,020 wolves are being managed in Montana, Idaho, and Wyoming under the federal Endangered Species Act. From 1987 to December 2005, 528 cattle, 1,318 sheep, 83 dogs, 12 goats, 9 llamas, and 6 horses were confirmed killed by wolves, and over $550,000 was paid from a private damage compensation fund. To help restore the wolf population, we used 22 variations of non-lethal control tools, relocated wolves 117 times, and killed 396 wolves to reduce conflict between wolves and livestock. A variety of tools, including regulations that empower the local public to protect their private property, reduced the probability of wolf-caused damage. This wolf population was restored, the risk of livestock damage reduced, and public tolerance of wolves improved through an integrated program of proactive and reactive non-lethal and lethal control tools. Reduced conflict increases the potential to restore wolf populations.

KEY WORDS: *Canis lupus*, control, depredation, livestock, non-lethal, predator control, removal, wolf

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INTRODUCTION

The gray wolf (*Canis lupus*) is the most widely distributed large carnivore in the northern hemisphere (Nowak 1995). In the western United States, elimination of wild prey by colonizing settlers, wolf depredation on livestock, and negative public attitudes towards wolves resulted in the extirpation of wolf populations by 1930 (Mech 1970, McIntrye 1995). In 1974, gray wolves were protected and managed by the U.S. Fish and Wildlife Service (USFWS) under the federal Endangered Species Act of 1973 (ESA).

Wolf recovery would have been impossible if abundant wild ungulate prey had not already been restored by sportsmen and the state wildlife agencies (Bangs *et al*. 2004). As a result of abundant wild prey and increased protection of wolves in Canada, the first recorded den in the western U.S. in over 50 years was established in Glacier National Park in 1986 by wolves that naturally dispersed from Canada (Ream *et al*. 1989). Wolves from Canada were reintroduced to central Idaho and Yellowstone National Park in 1995 and 1996 to accelerate restoration (USFWS 1994*a*, Bangs and Fritts 1996, Fritts *et al*. 1997). Restoration of wolves emphasized legal protection, minimizing conflicts with livestock, and building local public tolerance (USFWS 1987, 1988).

The wolf population in the northern Rocky Mountain (NRM) states of Montana, Idaho, and Wyoming grew from 10 wolves in 1987 to 1,020 wolves by late 2005 and is biologically recovered (USFWS *et al*. 2006). Humans

cause up to 85% of adult wolf mortality in the NRM (Pletscher *et al*. 1997, Bangs *et al*. 1998), and the two most common causes of radio-collared wolf death (around 10% each year; D. W. Smith *et al*., unpubl. data) have been agency control and illegal killing (Bangs *et al*. 1998). Resolving conflicts, both perceived and real, between wolves and livestock remains the dominant social issue for the recovery program (Bangs and Shivik 2001, Bangs *et al*. 1995, 2004, 2005*a*).

Our program enlisted the expertise and standard practices of USDA Wildlife Services (WS) to investigate reports of wolf caused-damage (Paul and Gipson 1994, Roy and Dorrance 1976). When wolf-caused damage is confirmed, we implement those tools we believe are most likely to foster wolf recovery and reduce the potential for further damage. We, numerous volunteers, and various private groups implemented programs to reduce or mitigate wolf-caused damage. In addition, livestock producers have recommended and implemented many modifications in their grazing operations, at direct cost to them. Most importantly, they have also shown remarkable tolerance for wolf damage, wolf management regulations, and wolf managers on their private land and public land grazing allotments.

From 1987-2005, wolves in the NRM were confirmed to have killed a minimum of 528 cattle and 1,318 sheep (USFWS *et al*. 2006). Wolf depredation was a relatively rare cause of livestock death (Bangs *et al*. 1995, 2005*a*) but confirmed losses are a fraction of actual wolf-caused losses, particularly in densely forested and remote public land grazing allotments (Oakleaf *et al*. 2003). Cattle and sheep were killed most often during May-October when grazing is dispersed on remote public lands and young livestock are most available (Bangs *et al*. 2005*a*, Bradley 2003, Musiani *et al*. 2005). While unimportant to the regional livestock industry, wolf depredations can affect the economic viability of some ranches. Other types of livestock are uncommon in the NRM, and wolves only killed 12 goats, 9 llamas, 6 horses, and 83 dogs, primarily livestock herding and guard dogs and hunting hounds.

Since 1987, wolf control actions have relied on a variety of tools including non-lethal deterrents, relocating wolves 117 times (Bradley *et al*. 2005), and killing 396 wolves (USFWS *et al*. 2006). Every wolf control technique attempts to balance the public desires for wolf restoration and livestock safety. The relatively rare and dispersed nature of wolf depredation and the vast number of variables associated with each depredation made it nearly impossible for us to scientifically determine the true effectiveness of each tool. We can only say with confidence that our integrated control program allowed the wolf population to exceed recovery objectives, and occasionally some tools, in some situations, and under some conditions appeared to reduce the potential for wolf depredation, which reduced some public animosity towards wolves. We discuss each tool we have used, the theory behind it, and its advantages and drawbacks.

NON-LETHAL METHODS

We implemented a wide variety of tools to reduce conflict between wolves and livestock that did not involve removing wolves (Bangs and Shivik 2001; Shivik *et al*. 2002, 2003; Shivik 2006). Non-lethal methods were the tools of choice, particularly when wolf numbers and distribution were most limited. The effectiveness of nonlethal tools seemed to be enhanced when several types were used in combination. But just as removal is not a replacement for non-lethal tools, non-lethal tools are not replacements for targeted removal (Breitenmoser *et al*. 2005, Treves and Naughton-Treves 2005). Both appear useful and to enhance each other's effectiveness. A key characteristic of grazing in the NRM is its seasonality. Cattle and sheep are the dominant livestock in the NRM and are most vulnerable in summer. In winter, livestock are usually fed, confirmed to valley bottoms or shipped out of wolf range, more concentrated, and nearer to humans, and thus are less vulnerable to wolf predation. Even temporarily-effective wolf control may allow that year's grazing cycle to be completed without significant losses to livestock or significant wolf removal. Many of the non-lethal tools listed below may be less applicable in areas with longer grazing seasons and calving seasons or different livestock grazing patterns.

1. Focus Wolf Population Recovery in Areas with Lowest Potential for Livestock Conflict

We attempted to restore wolf populations to the areas with abundant wild prey and fewest livestock (Oakleaf *et al*. 2006, USFWS 1987).

***Theory*:** Abundant wild prey and few livestock reduces conflict. ***Advantages*:** Wolf restoration to areas with no or few livestock reduces damage and public controversy. However, wolf predation on wild ungulates remains a concern of many hunters and outfitters. Abundant wild prey can sustain more wolves in areas with few livestock. Less conflict reduces costly and controversial agency management. Such areas are typically in secure public ownership. ***Drawbacks*:** Areas without livestock are limited, usually the least biologically productive, and in winter may be devoid of native prey. As wolf populations expand they continually move into livestock production areas.

2. Maintain a High Level of Radio-Collared Wolves in the Population

We maintain radio-collars in 20-30% of the wolf population and focus monitoring on packs, particularly those where depredations have been confirmed. The overall program cost over $2.6 million in 2005 (USFWS *et al*. 2006), and a large portion of those costs were associated with intensive telemetry monitoring.

***Theory*:** Intensive monitoring of wolf packs allows for better detection of problems, and more timely, effective, and targeted control. ***Advantages*:** Radio telemetry allows wolf monitoring at a level that is otherwise impossible. Illegal killing may be inhibited. It can enhance the effectiveness of non-lethal deterrents, can focus removal on specific individuals, and makes removal more timely and effective. ***Drawbacks*:** Capturing, collaring, and monitoring radioed wolves is extremely time intensive and expensive and may not be sustainable for larger populations. Helicopter darting and aerial monitor-

ing are potentially dangerous to field personal. Wolf capture resulted in a 3% mortality rate among wolves handled. Trapping results in non-target captures, including domestic dogs, which can be very emotional and controversial. Such intensive and intrusive management enforces unrealistic public perceptions about wolves and the resources needed to manage them, compared to other wildlife management and damage control programs in the western U.S.

3. Trap or Helicopter Dart, Radio-Collar, and Release Wolves On-Site

We often capture wolves after a confirmed depredation. They are radio-collared and released on site, so the situation can be intensively monitored while other courses of action are considered.

***Theory*:** Capture disrupts wolf activity and behavior of both the captured wolf and any accompanying pack members. This may reduce wolf activity and depredation in that immediate area for a period of time. ***Advantages*:** Radio-telemetry enhances our ability to determine which wolves might be responsible for depredations. Capture at the depredation site often targets the wolves responsible. It allows for more targeted and effective subsequent control. ***Drawbacks*:** Capture is time intensive and expensive. Because wolf pack territories range from 200-500 mi^2, capture is only effective around livestock carcasses for short time. Traps must be checked daily, if wolves are intended for release. Some areas do not facilitate wolf capture because conflicts with access, vegetation, terrain, guard dogs, livestock, other predators (grizzly bears, *Ursus arctos horribilis*), the public, and other land uses (wilderness or private land).

4. Increased Agency Monitoring of Wolves in Conflict Situations

We intensify our monitoring of wolves when livestock depredations have been suspected or confirmed, including increased ground and aerial telemetry.

***Theory*:** Intensive monitoring provides the opportunity to learn more about individual depredation events. It provides local ranchers with some sense that their problem is being closely examined, and that future problems will not go undetected or unresolved. It facilitates decision-making, communication, and coordination between responsible agencies. ***Advantages*:** Intensive monitoring allows for increased positive dialog between agencies and producers. It buys time without removing wolves, and helps detect whether problems continue and what other tools maybe most effective. It enhances subsequent control if it is required. ***Drawbacks*:** Increased monitoring often involves telemetry that is expensive and time consuming, and from the ground is limited by terrain. It has little potential to reduce livestock hunting by wolves. It reinforces the perception that compared to other wildlife, the presence of wolves mandates constant vigilance and intervention.

5. Loan Radio Receivers and Antennas to Ranches with Confirmed Wolf Presence

We loan radio telemetry systems (under $1,000/unit) to ranches that have had depredations so they can locate radio-collared wolves in their area.

***Theory*:** Ranchers could monitor wolf activity frequently and detect when wolves were near livestock, and thus be better able to protect their livestock or detect additional conflicts. The ability to detect wolf presence provides ranchers with an increased sense of security. ***Advantages*:** Ranchers believed knowing wolf locations were important to them (Montag *et al*. 2003). The ranchers are often nearby, even at night. It doesn't require much agency personnel time, while it empowers ranchers to determine how much effort they want to put into detecting radioed wolves. ***Drawbacks*:** It puts the burden and expense of detection on ranchers. Only radio-collared wolves can be detected. Buying, maintaining, and keeping track of equipment is time-consuming and expensive. Detection is limited to line of sight and a few miles on the ground. It does little to affect wolf livestock hunting behavior. Producers may be hesitant to give receivers back or share with their neighbors. Telemetry can facilitate, or raise concern about, illegal killing.

6. Move Centers of Wolf Activity from Livestock Concentrations by Disturbing Dens and Harassing Adults/Pups at Rendezvous Sites

In areas where intensive livestock grazing would occur in summer, we disturbed soon-to-be occupied dens (early April), and we harassed wolves with older (8-week) pups at rendezvous sites (June), causing those wolves to raise pups farther away from areas of concentrated livestock grazing.

***Theory*:** Wolf activity and depredation are most concentrated around dens and rendezvous sites (Oakleaf *et al*. 2003). Reducing the frequency of interaction between wolves and livestock could reduce the potential for conflict. ***Advantages*:** Disturbance caused wolves to raise pups elsewhere and reduced wolf interaction with livestock. We have not documented any wolf mortality or reproductive failure due to this harassment. ***Drawbacks*:** While wolves tend to move back to their historic den and rendezvous sites, they could move to worse situations. It is only applicable in a few cases and during limited times of the year. Some landowners will not allow access.

7. Supplemental Feeding of Livestock or Not Grazing in Areas and Times of Past Chronic Conflict

We have informed livestock producers that availability of vulnerable natural prey may reduce livestock depredation, and that depredations tend to occur in the same areas. We have encouraged some producers to delay turn-out (often in May) until young wild ungulates are available (beginning in June) to wolves, until wolves can more easily move their pups away, or to avoid grazing in certain areas where conflicts have chronically occurred. Some producers voluntarily modified their grazing strategies to reduce their risk of having wolf-caused damage. Conservation groups have also assisted some producers by providing additional feed/grazing areas so livestock could be turned out into wolf range later in spring, or onto alternative pastures. Land management

agencies attempt to accommodate grazing rotation flexibility to reduce conflict.
***Theory*:** Depredations are more likely during certain times of year and in certain areas. Separating wolves from livestock at those times or areas reduces depredation and control. ***Advantages*:** These actions are solely voluntary. They recognize and try to compensate producers for their increased costs/risks. Separation of livestock from wolves reduces livestock loss and subsequent wolf removal. ***Drawbacks*:** These actions are funded by private groups because public funds aren't typically used in this manner. Alternative grazing areas are scarce. They may require additional effort and resources from producers.

8. Supplementally Feed Wolves at Dens or Feed Orphan Pups

Occasionally, dispersing wolves follow migratory ungulates to lower elevation wintering areas, find mates, and then den nearby in April. Unfortunately, in May many ungulates disperse to higher elevations to give birth and summer. This results in wolves trying to raise pups while near few wild prey but abundant livestock. In the early stages of wolf recovery, we provided wild ungulate carcasses (typically road-kill) near wolf dens or to orphaned pups, to localize wolves near den/rendezvous sites to reduce the risk to livestock.
***Theory*:** Supplemental feeding localizes wolf movements, provides abundant food for pups, and temporarily reduces the need for adults to hunt. ***Advantages*:** Road-killed ungulates can usually be obtained, wolves readily scavenge, and wolf activity remains more focused around the den/rendezvous site and feeding area. It can allow time for pups to mature so adults can move them to more remote areas, or for wild neonates to become available. Feeding can prevent orphaned pups (before October) from starving. ***Drawbacks*:** It is fairly time intensive to obtain, move, and deposit ungulate carcasses. Carcasses can draw in other predators, such as grizzly bears. Feeding may habituate wolves and increase their exposure to illegal killing.

9. Delay Wolf Removal if Depredations Appeared to Result from an Unusual Circumstances, Livestock are Soon to be Removed from Grazing Allotments, or if Human Hunting of Big Game is About to Begin

One of the conditions for initiating wolf removal is that depredations are likely to continue without control (USFWS 1988). Confirmed wolf depredation can be sporadic and may even stop on its own, for a wide variety of reasons. We just monitor these situations closely if we believe they might resolve themselves through other processes.
***Theory*:** Wolf conflicts with livestock can stop without intrusive management if the depredation appeared to result from an unusual circumstance, i.e., injured livestock, livestock are soon to be removed from the area anyway, or big game hunting seasons provide an abundance of carrion for wolves so they need not hunt as hard for food. ***Advantages*:** Waiting costs very little time and effort; it may help get through a grazing season, allowing more wolves to disperse or breed the next year. It provides more time to determine if conflicts continue and, if so, what other control tools are most appropriate. ***Drawbacks*:** Waiting and monitoring does not reassure or give closure to the livestock producer and can result in further depredations. Waiting can be viewed as just increasing future problems. It is often limited to those times of the year when depredations are already infrequent.

10. Modify Livestock Husbandry Practices (carcass disposal, sick/wounded livestock, larger livestock)

We provide information to livestock producers that some livestock husbandry techniques may affect the relative risk of wolf damage. Wolves readily scavenge on livestock carcasses, so livestock carcass removal can reduce wolf presence, although recent research does not indicate a relationship to depredation (Bradley and Pletscher 2006, Mech *et al*. 2000). Twice we documented situations where wolves were around livestock without conflict, but within days they attacked injured livestock placed in the same pastures. Both instances involved young calves, one killed after being treated for severe cuts by a fence, and another after being treated for frostbite. Oakleaf *et al*. (2003) indicated wolves keyed into livestock vulnerability and killed the smallest calves on remote public land grazing allotments. Adult cattle and horses are less vulnerable than calves and sheep. These types of changes are strictly voluntary for livestock producers, if their livestock husbandry methods are within traditional standards. However, in a few situations since 1987, we have opted to not remove wolves because the livestock husbandry practices associated with that particular depredation constituted an unusual attractant. One situation involved overcrowding and mass starvation of domestic sheep in a fenced winter pasture. Their carcasses attracted wolf scavenging and depredation.
***Theory*:** Wolves are very sensitive to prey vulnerability and livestock depredation can be influenced by livestock husbandry practices that affect livestock vulnerability. ***Advantages*:** Any modifications in livestock husbandry by producers are entirely voluntary, allowing each producer to evaluate their own potential costs and benefits. Some livestock husbandry practices are relatively easy to implement and may have other benefits. Providing information is usually well received and non-threatening to producers, who typically are eager to reduce the potential for wolf-caused losses, if practical and economical. ***Drawbacks*:** Information may be simply ignored, and livestock depredations can continue with the expectation that the government is responsible for wolf removal. Some people mistakenly believe that changes in livestock husbandry will prevent wolf depredation and that wolf depredations are often the producer's "fault". Some conditions (sick livestock, carcass removal) are difficult to detect and resolve in remote areas.

11. Allowing Non-Injurious Harassment by the Public

The federal regulations (USFWS 1994*b*) developed to manage reintroduced wolves allow anyone, anywhere, at any time, to harass wolves in a non-injurious manner,

such as rapidly approaching them, making loud noises, etc.

***Theory*:** Harassing wolves makes them more fearful of people and less likely to frequent areas with high levels of human activity, such as intensive livestock production areas. ***Advantages*:** It provides something that every person can do to help themselves and to feel dominant over wolves. Harassment helps reduce wolf habituation to humans and it may reduce their use of human-dominated landscapes. It is harmless to wolves. Wariness may reduce wolf vulnerability to illegal killing. ***Drawbacks*:** Wolves quickly learn harassment isn't injurious. They can learn to avoid human activity by being more active at night or keeping their distance. Such harassment may not transfer to avoidance or reduced hunting of livestock.

12. Light and Siren Scare Devices

We used propane cannons and light and siren devices, including a Radio Activated Guard (RAG) that is triggered by radio-collar signals, to frighten wolves from areas with livestock.

***Theory*:** Wolves are afraid of novel stimuli, and strange noises and light can temporarily displace them. RAG can detect and record approaches of individual radioed wolves, allowing for more targeted control. ***Advantages*:** Scare devices frighten wolves from localized areas, at least temporarily. They work automatically, at night, and can alert producers. Propane cannons and standard light and siren devices are relatively inexpensive ($300) and mobile. ***Drawbacks*:** Wolves habituate to strange stimuli, especial when they operate regardless of wolf proximity. They require effort to maintain. They can frighten livestock or annoy people if close to dwellings. RAG devices ($3,000) require training and radio-collared wolves to work, and they are too bulky to use in remote areas. Individual devices cover a relatively small area and require livestock be confined.

13. Less-than-Lethal Munitions

Livestock producers requested tools to deal with what they perceived as increasingly bold behavior of wolves near residences and habituation to non-injurious scare devices. We investigated a wide range of non-lethal projectiles and developed a program of agency-issued permits and training, and we provided 12-gauge shotgun cracker shells, bean bag shells, and rubber bullets to shoot at wolves. Over 200 permits were issued, and wolves were fired at numerous times. Only 3 wolves were reportedly hit, and none were permanently injured. A few landowners reported that some wolves that once stood and looked at them became more wary and ran at the sight of humans after being shot at.

***Theory*:** These munitions can injure wolves without killing them and cause wolves to act more wary. These munitions provide a means to address a public concern short of killing wolves. Livestock producers felt better about being able to shoot at wolves. ***Advantages*:** They limit the progression of bold wolf behavior, so wolves stay more wary of humans. Training provides a positive interaction between landowners and agency personnel prior to serious conflicts. These munitions shoot up to 100 m and can hurt a wolf or explode near them. They provided some tools for landowners to deal with wolves that were repeatedly approaching houses, dogs, or were behaving boldly. ***Drawbacks*:** Munitions require a wolf be seen and at close range, and the landowner have a shotgun ready at that time. These munitions are difficult to obtain and are potentially lethal at close range. Cracker shells can start wildfires. Agency training is mandatory to stress gun, human, and fire safety. Close encounters with wolves are relatively rare, and interest in obtaining the permits waned after a few years. The permit, training, and monitoring processes were time-intensive.

14. Fencing

We provided information to landowners that fencing may be helpful to contain livestock and/or reduce the probability of wolf attacks on their livestock and dogs. We worked with conservation groups to assist some landowners to acquire wire (normally hog wire up to 2 m high) or electric fencing to better protect their livestock.

***Theory*:** Good fencing makes it much more difficult for wolves to attack livestock or dogs, and it confines livestock to areas where they can be better protected. ***Advantages*:** Fencing can be an effective barrier to wolves and other predators, and it is durable. Electric fencing for temporary night pens can be moved and set up quickly. Fencing can facilitate control by restricting wolf movements. ***Drawbacks*:** Fencing is expensive to purchase and install, and usually it protects a relatively small area, like night pens for sheep, small numbers of hobby livestock, or pets. It requires livestock be moved in and out of it, a time-intensive process for the landowner. Livestock confined for long periods can have husbandry issues with diseases, birthing, cleanliness, and foraging. Wolves can easily go through barbed wire fence or jump over short fences, while woven wire and taller fences can be barriers to other wildlife. Wolf depredation is so uncommon that if fences become burdens to producers, they stop using them.

15. Fladry

Fladry is a series of cloth flags on a rope or on strand wire fencing. The unique behavior of wolves lets it act like a solid fence for some time (Musiani *et al*. 2003). We used fladry to help producers better protect livestock confined behind barbed wire fencing or to extend the height of fencing that wolves were jumping over.

***Theory*:** Wolves avoid crossing fladry, and it provides a temporary barrier between wolves and livestock. ***Advantages*:** Fladry is more portable and at $781/km is much less expensive to purchase and install than wire fencing. It can be quickly installed over fairly large areas by a few people (4 km/day). Fladry does not appear to inhibit the movements of other wildlife. Turbo-fladry ($1,328/km) incorporates electric shock and is much more effective. ***Drawbacks*:** Fladry must be constantly maintained, due to wind and livestock-caused damage. Fladry is only effective for weeks. Wolves habituate to it or may walk adjacent to it until they can find a place to cross.

16. Guard Dogs

Guard dogs have been used to protect livestock for centuries and are widely used to protect livestock (primarily sheep) in the NRM today. We provided information about guard dogs to livestock producers. We facilitated contact between livestock producers and conservation groups that helped cost-share guard dogs in wolf range. We bought 6 spiked leather dog collars to test their use at protecting dogs.

***Theory*:** Guard dogs detect wolves near livestock and bark, approach, or fight with them, alerting the herders. They can reduce successful attacks by wolves (Bangs *et al*. 2005*b*). ***Advantages*:** Most sheep and some cattle producers already employ guard dogs. Cost-sharing reduced their costs to increase the number of dogs required to be effective in wolf range. Guard dogs require little care and operate 24 hours a day. A spiked collar apparently saved the life of one guard dog. ***Drawbacks*:** Wolf packs search out, attack, and kill guard dogs, so multiple dogs are often needed and herders must be nearby to protect dogs. A dog may cost thousands of dollars, feeding can be expensive, and good dogs require acclimation to the livestock to be protected. Interest to try spiked collars was very limited, and they were rarely used in the field because the sharp spikes were perceived as nuisance to the guard dog, other dogs, equipment, and herders.

17. Extra Sheep Herders and Cattle Riders

We relayed information from some ranchers, who indicated that they believed increased riding/herding of their livestock helped reduce wolf presence. We participated in a voluntary test program by various private groups and the USDA National Resources and Conservation Service to provide funding for extra riders ($2,000 per month each) to increase human presence on some private and public cattle grazing allotments where wolf depredations had previously occurred. We radio-collared wolves in those areas and provided radio telemetry frequencies and receivers to the riders. Producers felt this program would help detect depredations and might reduce losses.

***Theory*:** More human activity around grazing livestock might cause wolves to use those areas less and reduce the potential for conflict. Daily checking of livestock would reduce producers' fears that extensive depredations would occur before losses were detected. ***Advantages*:** Extra riders were subsidized and demonstrated that wolf advocates recognized the costs of wolf restoration to producers. Livestock were monitored more closely, which produced other benefits such as riparian protection, better distribution of grazing pressure, and detection of other problems, such as livestock health. Herders can reduce risk to sheep and to guard and herding dogs. Riders might find dead livestock sooner, improving accuracy of agency cause-of-death investigations. ***Drawbacks*:** It is uncertain if more human presence among widely distributed livestock like cattle reduces the risk of wolf depredation. Unless subsidized, extra riders may cost more than they save in lost livestock. It may be difficult to find good herders/riders, because wages are typically low and the work is hard, especially since it requires nighttime surveillance and camping with livestock.

18. Electric Dog Training Collars

Dog training collars can modify canid behavior, and we attempted to test whether wolves that attacked cattle could learn not to. We unsuccessfully attempted penned experiments on 2 different groups of wolves that would have been killed for attacking cattle (Asher *et al*. 2001, Shivik *et al*. 2002). Those wolves were then released back into their territory. Nearly all depredated again and were killed.

***Theory*:** Negative stimuli, such as an electric shock, can modify animal behavior. Successful attacks on cattle may be a learned behavior. Wolves and possibly packs (because wolves are social learners) might be taught to avoid certain areas or certain types of prey. ***Advantages*:** Research indicated this type of training is possible (Shivik *et al*. 2002, Schultz *et al*. 2005) and offered a potential solution to a cycle of depredation, wolf removal, and wolf recolonization in areas of chronic annual conflict. ***Drawbacks*:** Initial research was unsuccessful in penned wolves because of their overall reaction to confinement and no training was evident (one wolf may have been shocked once). Monitoring and caring for wolves required a large pen and was time-intensive. Some people considered this inhumane, which resulted in thousands of complaints.

19. Regulations to Empower Producers to Protect Their Own Livestock

Based upon public comment, we tried to empower local people to deal with problem wolves, as long as wolf recovery would not be jeopardized. People could harass any wolf, shoot those attacking livestock or dogs, and help with agency control by means of less-than-lethal munitions and shoot-on-sight permits.

***Theory*:** People may be less likely to illegally kill wolves if they feel they can legally address problems themselves. Local people are more likely to implement immediate control on the problem wolf than agencies can, days after a depredation. ***Advantages*:** These types of regulations are familiar and used by states to manage problem mountain lions (*Puma concolor*) and black bears (*Ursus americanus*). People can resolve some problems legally, reducing agency control costs and workload. In-the-act control targets problem individuals. ***Drawbacks*:** Few depredations are ever witnessed. Timely reporting (within 24 hrs) can be difficult in remote areas. The checks and balances needed to reduce abuse require timely and costly law enforcement and agency investigations.

20. Compensation

The federal government mitigates for wildlife damage by management intervention but does not pay compensation. In 1987, Defenders of Wildlife (DOW) started a privately-funded program that compensates ranchers up to $3,000 per animal for confirmed (100%) and probable (50%) damage to livestock and livestock herding and guarding dogs (Fischer 1989, Stone *et al*. 2006). DOW

ties proactive and non-lethal strategies to avoid or reduce wolf depredation to compensation. DOW uses WS field reports as the basis for compensation but deals directly with the affected producer. Over $550,000 has been paid. DOW has also spent $150,000 to assist producers implement and develop non-lethal deterrents to wolf depredation since 1999. Since 2003, the state of Idaho provided up to $99,000/year for compensation for suspected wolf-caused missing livestock under some circumstances. Montana, Idaho, and Wyoming intend to implement state wolf-damage compensation programs when wolves are removed from federal protection.

***Theory*:** Compensation shifts some of the economic burden for wolf restoration away from producers (Montag *et al*. 2003, Nyhus *et al*. 2005). Compensation helps reduce negative attitudes towards wolves and attempts to illegally kill them. ***Advantages*:** Private compensation is widely supported by the general public and is accepted by most producers. Private compensation is timely and effective at mitigating some of the financial burden to livestock producers. A relatively fraud-free private compensation program is possible because of the existence of a WS field program that already professionally investigates, confirms, and documents all causes of predator damage to livestock. ***Drawbacks*:** Compensation only mitigates for damage and does not provide an incentive for allowing wolves to be present (Nyhus *et al*. 2005). Compensation does not reimburse producers for the full costs of wolf damage, which may include unconfirmed losses, missing livestock, possible weight loss, possible lower pregnancy rates, increased herding and livestock monitoring costs, and their time involved to report and help verify damage. Compensation programs are subject to fraud and abuse. WS investigations/reports were not designed for compensation purposes.

21. Reducing/Retiring Public Land Grazing Allotments

Some land management agencies reduced grazing on public land, usually for habitat, water, fish and wildlife, or other land management issues. No grazing allotments have been reduced solely to benefit wolves, but reductions, particularly in range sheep operations, can reduce risk of depredation. On a willing seller basis, conservation groups have purchased and retired some grazing allotments to reduce the cycle of livestock conflict and predator control.

***Theory*:** Separation of large predators and livestock during the summer grazing season reduces risk and need for predator control. ***Advantages*:** Voluntary grazing lease retirement benefits the livestock producer who has chronic damage and reduces the need for predator control. These cooperative agreements may have benefits to other wildlife species. ***Drawbacks*:** Most (70% of cattle and 48% of sheep) wolf depredations occur on private land (Bangs *et al*. 2005*a*). There can be strong political opposition to allotment retirement and modifications in agency land-use missions. Grazing is so widespread and wolves have such large home ranges that removing/ reducing livestock within just one wolf pack territory, while significant, is a difficult and expensive undertaking.

22. Research and Public Outreach

We have cooperated in a host of science-based research projects looking at wolf/livestock relationships to obtain better knowledge and look for ways to reduce damage. Since 1987, we gathered and widely-publicized accurate information by giving thousands of media interviews and almost 1,000 public presentations.

***Theory*:** Increased knowledge provides the opportunity for better decision-making. ***Advantages*:** Research can provide more accurate information to all parties and perspectives, and can help identify ways to reduce risk. Science can remove some of the human emotion from controversial issues. Personally-conducted outreach reduces misinformation and rhetoric, and it lets us hear, first-hand, the concerns of livestock producers/ landowners and wolf advocates. ***Drawbacks*:** Wolves are highly symbolic, and issues often deal more with human values and opinions than biological facts. Research can identify problems and additional questions more rapidly than it identifies solutions or validates theories. Research and public outreach are time consuming and expensive. Research and traditional outreach methods do little to change core human values.

WOLF REMOVAL

The historical model for resolving wolf and livestock conflict has been wolf removal or extirpation (McIntrye 1995, Treves and Treves-Naughton 2005). We use "removal" to mean taking wolves out of the wild, even if temporarily. Since 1987, we have temporarily held wolves in captivity for various reasons, relocated wolves 117 times, and killed about 6% of the wolf population annually to reduce livestock losses. Removal affects wolf density and distribution, but wolf populations can withstand substantial removal (<34% annually) and still grow (review in Fuller *et al*. 2003). Removal addresses immediate conflicts but does not prevent conflicts from reoccurring in that area the following grazing season (Bradley 2003, Musiani *et al*. 2005). Removal results in a cycle of wolf colonization, depredation, and wolf removal that repeats itself (Bradley 2003, Musiani *et al*. 2005). This cycle may be an unavoidable consequence of wolf restoration but is unsatisfying to livestock producers, wolf advocates, wolf managers, and the general public. Eventually, society will determine how many wolves there should there be, where, and what level of conflict is 'tolerable.' Implementation of those decisions will likely involve regulating the rate of wolf removal.

1. Temporarily Holding Problem Wolves in Captivity

In the early stages of wolf recovery, we raised a few orphaned pups in captivity until they were old enough to survive independently. At times, depredating wolves were held in captivity before being released back into the wild or relocated.

***Theory*:** Disrupting wolf behavior by temporarily holding them in pens is very stressful to them and may reduce their tendency to hunt livestock. Holding pups too young to fend for themselves until they can forage successfully allows them to survive. ***Advantages*:** Wolves adapt relatively well to captivity but remain frightened of

humans. Wolves in captivity cannot attack livestock. Wolves can be released when depredations are less likely. Wolves held over a month will still use their old territory. ***Drawbacks*:** Large wolf-proof fence pens (chain-link, 10' high, with 2' overhang and 4' skirt) are difficult to put up, expensive, and must be in remote and secure areas. Wild wolves typically injure their canine teeth and often their feet while being held in chain link pens. Wolves held in kennels developed health issues (cut mouths, bedding sores, lethargy, etc.). Pups raised in pens often later became nuisances. Caring for captive wolves was time-consuming.

2. Relocation

From 1987-2001, we relocated wolves 117 times. All released wolves were radioed-collared. We have not relocated wolves since 2001, because successful relocation is largely dependent on release into high-quality vacant habitat, which became limited (Bradley *et al*. 2005).

***Theory*:** Removing wolves from areas with livestock depredation reduces the potential for continued depredations there. Relocated wolves are disoriented and are less likely to immediately resume killing livestock. We hoped they would resettle in areas with a lower potential for conflict. ***Advantages*:** Wolf removal reduced immediate problems with livestock. Some relocated wolves survived, did not depredate, and contributed to overall wolf population recovery. Radio-collars allowed relocated wolves to be closely monitored. ***Drawbacks*:** Relocation was expensive, and survival of relocated wolves was low (Bradley *et al*. 2005). Usually, only a few wolves can be captured, and it is much easier, quicker, and less expensive to kill them. Local producers supported wolf relocation, but producers where the wolves were released did not. Relocated wolves caused additional depredations.

3. Regulations Allowing Public Removal of Problem Wolves (Non-Permitted and Permitted Defense of Property Rules)

The USFWS allowed more liberal killing of problem wolves by the public as wolves became more common. The first wolves in northwestern Montana were listed as endangered, and the public was not allowed to kill them (USFWS 1988). In 1995, when the USFWS first reintroduced wolves, regulations (USFWS 1994*b*) allowed private landowners to shoot wolves seen physically biting and grasping cattle, sheep, horses, or mules. Beginning in 2005, landowners and federal grazing permittees in states with approved wolf plans could shoot wolves harassing, molesting, or attacking livestock, livestock herding and guarding animals, and dogs (almost the same defense of property regulations used by states for mountain lions and black bears) (USFWS 2005). Beginning in 1997, shoot-on-site permits were issued to private landowners with chronic depredation problems that the agencies had difficulty resolving. Since 1994, approximately 7% of all problem wolves legally killed have been shot by the public. ***Theory*:** Producers were unlikely to shoot more than one wolf at a time, making others more wary. The public can address some of their own problems if checks and balances are in place to reduce abuse, thus reducing agency workload and costs. ***Advantages*:** Local producers were more likely to target the offending wolf than agency control. In-the-act removal eliminated the need for subsequent agency control. Shooting at wolves may teach them and other pack members to be more wary of people and areas with high levels of human activity. When people can immediately address their own problems, they might be more tolerant of wolves. Federal rules become more like familiar state 'defense of property' regulations, reducing animosity towards federal authority and wolves. ***Drawbacks*:** Wolves can avoid humans by being more active at night. Any legalized killing of wolves by the public opens the door for abuse, so law enforcement investigations are required. Killing wolves is always controversial.

4. Agency Removal (Relocation, Killing)

The USFWS authorized the killing (including legal killing by the public) of 396 problem wolves from 1987 through 2005. Wolves were killed by aerial gunning, trapping, and shooting from the ground. Killing problem wolves reduced current year conflicts by reducing wolf density in conflict areas, removed the offending individual or pack, eliminated packs where chronic livestock depredations occurred (high conflict zones), reduced a pack's overall demand for food, and made it more difficult for the fewer remaining pack members to kill large prey like cattle. We implement lethal control after we determine that non-lethal methods are unlikely to be successful, livestock were clearly killed by wolves, depredations are likely to continue, and there is no evidence of intentional feeding or unnatural attraction of wolves. We strive to implement control in an incremental fashion. For example, a pack of 8 wolves is confirmed to have killed livestock and lethal removal is warranted. We remove a wolf or two, often specific individuals or age classes, and then wait to see if the problem continues. If more depredations occur, we remove a few more individuals to see if that prevents further conflicts. We continue incremental removal until depredations stop, even if that eventually results in removal of entire packs, which has occurred in about 20 cases.

***Theory*:** Lethal removal of wolves can stop depredations there for one grazing season (Bradley 2003, Musiani *et al*. 2005). Lethal removal by agencies can be more tailored and sensitive to individual circumstances than control by private individuals. Effective removal of problem wolves increases local tolerance of non-problem wolves and reduces illegal attempts to kill wolves (USFWS 1988). ***Advantages*:** Agency killing can be targeted, swift, effective, and is tightly regulated. Wolf population status is factored into the rate of agency killing. Agency killing is used for problem mountain lion, bear, and coyote removal and is a familiar process to many livestock producers in the NRM. ***Drawbacks*:** Agency control is relatively expensive and safety can be a concern. Wolf control is controversial from both the viewpoint of wolf advocates (who want fewer wolves removed) and the livestock community (who want more wolves removed).

CONCLUSION

Only complete removal of either wolves or livestock eliminates the potential for wolf depredation. The continued presence of a viable wolf population in the NRM will require that a wide variety of non-lethal and lethal tools be investigated and implemented. Active management of wolf depredation on livestock will be required to maintain local public tolerance of wolves where the two overlap (Bangs *et al*. 2004, 2005*a*; Fritts and Carbyn 1995; Fritts *et al*. 1992, 2003; Mech 1995; USFWS 1994*a*). A viable wolf population can persist in the NRM, because large areas of suitable habitat are secure in public ownership, and state wildlife management agencies will continue to manage for high population levels for hunting, ensuring an adequate wild prey base for wolves. Wildlife managers should continue to attempt to minimize wolf-caused problems with livestock to reduce the likelihood of a backlash of public opinion against wolves. Such a backlash could result in widespread vigilantism or public calls for extermination programs (Mech 1995). Given some minimal level of secure habitat, wild prey, and damage management to minimize problems (and to increase human tolerance), wolf populations will persist.

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