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Adaptive use of nonlethal strategies for minimizing wolf–sheep conflict in Idaho

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Worldwide, native predators are killed to protect livestock, an action that can undermine wildlife conservation efforts and create conflicts among stakeholders. An ongoing example is occurring in the western United States, where wolves (*Canis lupus*) were eradicated by the 1930s but are again present in parts of their historic range. While livestock losses to wolves represent a small fraction of overall livestock mortality, the response to these depredations has resulted in widespread conflicts including significant efforts at lethal wolf control to reduce impacts on livestock producers, especially those with large-scale grazing operations on public lands. A variety of nonlethal methods have proven effective in reducing livestock losses to wolves in small-scale operations but in large-scale, open-range grazing operations, nonlethal management strategies are often presumed ineffective or infeasible. To demonstrate that nonlethal techniques can be effective at large scales, we report a 7-year case study where we strategically applied nonlethal predator deterrents and animal husbandry techniques on an adaptive basis (i.e., based on terrain, proximity to den or rendezvous sites, avoiding overexposure to techniques such as certain lights or sound devices that could result in wolves losing their fear of that device, etc.) to protect sheep (*Ovis aries*) and wolves on public grazing lands in Idaho. We collected data on sheep depredation mortalities in the protected demonstration study area and compared these data to an adjacent wolf-occupied area where sheep were grazed without the added nonlethal protection measures. Over the 7-year period, sheep depredation losses to wolves were 3.5 times higher in the Nonprotected Area (NPA) than in the Protected Area (PA). Furthermore, no wolves were lethally controlled within the PA and sheep depredation losses to wolves were just 0.02% of the total number of sheep present, the lowest loss rate among sheep-grazing areas in wolf range statewide, whereas wolves were lethally controlled in the NPA. Our demonstration project provides evidence that proactive use of a variety of nonlethal techniques applied conditionally can help reduce depredation on large open-range operations.

Key words: *Canis lupus*, coexistence, human–wildlife conflict, livestock damage prevention, predator

Gray wolves (*Canis lupus*) were nearly eradicated from the 48 conterminous states in the United States by the 1930s, largely to protect livestock producers from the threat of depredation (Young and Goldman 1944; Lopez 1978; McIntyre 1995). However, 4 decades later, in 1974, wolves were granted protection through the United States Endangered Species Act (16 U.S.C. 1531–1544, 87 Stat. 884), and due to successful reintroduction efforts and natural expansion, the species was reestablished in the northern Rocky Mountains (United States Fish and Wildlife Service et al. 2012, 2014). With the return of wolves, threats to livestock (primarily sheep, *Ovis aries*, and cattle, *Bos taurus*) again have become a source of conflict, and as a result wildlife agency managers often kill wolves that prey on livestock (Fritts et al. 1992; Mech et al. 2000; Bangs et al. 2006). However, killing depredating wolves without addressing the underlying causes of depredation only temporarily eliminates depredation attacks on livestock (Fritts et al. 1992; Gehring et al. 2003; Musiani et al. 2005; Harper et al. 2008; Bradley et al. 2015). For example, Bradley et al. (2015) found that recurring depredations were typically made by the next pack to occupy the vacant territory within 2 years, yet, in the Northern Rockies region, costs for investigations into livestock depredation, lethal control, and compensation for livestock losses exceeded $1.5 million in 2010 alone (Bradley et al. 2015).

Research indicates there is broader public support for nonlethal methods of predator control than for lethal methods (Arthur 1981; Reiter et al. 1999; Bruskotter et al. 2009; Holsman et al. 2014; Slagle et al., this issue). For example, in the state of Washington, recent surveys on public attitudes indicate growing opposition to lethal control of wild predators to prevent livestock losses (Duda et al. 2008). Public attitudes help shape public policy and, as a consequence, the nature of wildlife management programs. However, when surveyed, many livestock producers who had experienced livestock losses to wolves expressed skepticism concerning the anticipated effectiveness of nonlethal methods and the costs to implement them, whereas others expressed uncertainty regarding which methods were appropriate to use and when to use them (Stone 2009). Even established researchers of wolf and livestock management have mostly dismissed large-scale nonlethal predator deterrents as a viable alternative to traditional lethal control measures because they claim that nonlethal methods do not provide "an adequate or overall solution to this problem" and have "little or no long term value" in predator management efforts (Shelton 2004:3–4).

The willingness of livestock managers to adopt nonlethal techniques often relies on proof of their efficacy (Baker et al. 2008), which requires research aimed at determining their effectiveness across a variety of situations. Employing these measures for a small-scale farm or ranch is often feasible and inexpensive, and several specific methods have been studied at this level (Breck et al. 2002; Musiani et al. 2003; Gehring et al. 2010). However, most livestock killed by wolves in the northern Rocky Mountains of the United States are part of large, open-range grazing operations covering 4,000–40,000 ha or more. The question then becomes not just whether nonlethal deterrents can work but whether they are feasible in large landscapes. Some wolf scientists have cautioned that "all means of protecting livestock from wolves over large areas are largely ineffective and expensive" (Mech et al. 2003:336) yet also acknowledge that most methods remain untested (Harper et al. 2008). Others have dismissed nonlethal methods as too costly, impractical, and limited in their effectiveness due to wolves habituating to deterrent stimuli (Smallidge et al. 2008).

To date, there have been few landscape-scale trials of nonlethal deterrents in overlapping wolf and livestock range, and none that involved thousands of sheep in rugged national forests. Because wolves kill far more sheep than other types of livestock in the northern Rockies of the United States, including in Idaho (United States Fish and Wildlife Service et al. 2016), our goal was to determine if we could proactively and adaptively use nonlethal tools and techniques to significantly reduce losses of sheep to wolves while reducing lethal control of wolves across a large, rugged, and primarily forested landscape. Our case study compared the rate of sheep loss to wolves in a Protected Area (PA) and a Nonprotected Area (NPA) over 7 years. Details of our methods are given below, but critical here is that the PA and NPA were comparable in that both were on national forest lands, in adjacent areas, and occupied by wolves and both had a history of sheep losses due to wolf depredation. Furthermore, the sheep we monitored on the PA and NPA all belonged to several of the same 4 producers who participated in this project, and some of the same wolves from established packs ranged in both the PA and NPA. We emphasize that our goal was not to evaluate any single tool or method using a standard research design but rather to evaluate the holistic strategy of increasing the presence of humans, more diligence in handling of sheep (animal husbandry), and using a variety of nonlethal techniques in a proactive and adaptive fashion based primarily on wolf-monitoring information, grazing conditions, terrain, time of day, available resources, and accessibility.

Background

Wolves were reintroduced into Idaho in 1995 and 1996 as part of the northern Rockies wolf recovery efforts. Since that time, more than 2,400 wolves have been killed across the region in response to reported depredations involving more than 6,000 sheep and cattle (United States Fish and Wildlife Service et al. 2016). In the northern Rockies, significantly more sheep (4,514 confirmed) than cattle (2,274 confirmed) have been killed by wolves since 1987, when the 1st confirmed wolf depredations on livestock occurred (United States Fish and Wildlife Service et al. 2016). Approximately 200,000–220,000 sheep graze annually in Idaho, with estimated average annual losses of 20,000–30,000 from all mortality causes other than intentional slaughter for market (Idaho Sheep Loss Report 2013). Predator depredations account for 30–40% of all sheep mortality as estimated and reported by sheep producers (United States Department of Agriculture – National Agricultural Statistics Service 2010), with wolves accounting for ≤ 4.1% of total losses statewide in 2012, the most recent data available for sheep mortality loss in Idaho. While coyote (*Canis latrans*) depredation is the main cause of sheep losses in the northern Rockies, accounting for > 66% of depredations (United States Department of Agriculture – National Agricultural Statistics Service 2013), wolf depredation is more controversial and results in state-sanctioned efforts to reduce wolf numbers to address conflicts (Russell 2015). Nearly 64% of Idaho consists of federally owned or administered forests and other rangelands, almost half of which is leased to private individuals or corporations for rangeland grazing (Rimbey et al. 2014). According to the United States Department of Agriculture's (USDA) Wildlife Services Idaho Depredation Field Investigation Reports from 1995 to 2010, more sheep were killed by wolves on national forest lands (which are typically more remote and rugged) than on privately owned lands in Idaho.

Materials and Methods

Regional study area.—Our demonstration project was conducted in one of the largest sheep-grazing sectors in the Idaho wolf range (S. Boyd, Executive Director, Idaho Woolgrowers Association, pers. comm.). Domestic sheep and wolf packs share the same range each year from mid-June through early October on the Sawtooth National Forest, federally managed public lands that cover 854,052 ha in the states of Idaho (96%) and Utah (4%). This region includes sagebrush steppe, spruce-fir forests, and alpine tundra, among other vegetation types. The elevation ranges from 1,784 to 3,660 m, and the terrain is largely mountainous, unpopulated, and rugged. There are few maintained access roads in the more remote areas. The region is interspersed with lower-lying areas of concentrated human use and permanent settlement. Native mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), and moose (*Alces alces*) are present, among many other wildlife species, and game hunting is regulated by the state wildlife agency (Idaho Department of Fish and Game and Nez Perce Tribe 2014). Idaho Fish and Game reported a minimum of 6 documented packs of wolves in the Southern Mountains wolf management zone in 2007, 7 in 2008, 7 in 2009, 6 in 2010, 7 in 2011, 11 in 2012, 9 in 2013, and 8 in 2014 (Idaho Department of Fish and Game and Nez Perce Tribe 2008, 2009, 2010, 2011, 2012, 2013, 2014). Recreational use of the national forest (hunting, hiking, camping, skiing, and snowmobiling) is popular among local residents and tourists year round. Sheep traditionally are grazed in large bands attended by 1 or more shepherds, herding dogs, and livestock guardian dogs (LGDs). Bands are generally either "ewe–lamb" bands or "dry" bands. "Ewe–lamb" bands consist of about 850–950 ewes plus their lambs, usually totaling > 2,000 animals per band. "Dry" bands consist of a few hundred ewes early in the season, but later, after their lambs have been shipped, can grow to as many as 2,000 when older ewe bands and young replacement ewe bands are combined. Idaho range operators primarily employ Peruvian sheepherders to manage bands in the field. These bands slowly graze from lower to higher elevations in the spring and summer months after the native forage has become green. This seasonal cycle, known as transhumance migration, is an ancient pastoral tradition that has been practiced in areas around the world since sheep were first domesticated approximately 10,000 years ago. Sheep ranchers participating in the Demonstration Project have sheep bands that typically graze across a distance of more than 200 km each season.

Sheep grazing.—Although there are several farm flock operators in the vicinity of the study area that each manage up to a few hundred sheep in pastures, we were principally concerned with large-scale "range operators", producers who graze thousands of sheep across a vast landscape. Range operators graze lands with complex surface ownership, including their own deeded properties and public lands managed by various state and federal agencies. These range operators typically release (turn out) ewes and their lambs on the Snake River Plain in early April at an elevation of approximately 1,219 m, then travel slowly north through sagebrush steppe into mid-elevation country ranging from 1,524 to 2,438 m in May that offers greater topographic relief and is dissected by riparian corridors. In June, sheep bands enter the PA when they move into higher, more mountainous country ranging from 1,981 to 2,896 m in 1 or more national forests and where wolf packs establish their range. Bands of ewes and lambs are herded down from the high mountains in July or August to corrals in the valleys below where the lambs are weaned and shipped. The resulting "dry" bands then return to high elevation forest allotments for several weeks before the migration back to lower elevations begins in early- or mid-autumn. Rams typically are added to the ewe bands in August for breeding purposes. The bands are slowly herded to the vicinity of lambing sheds, located on the operator's deeded property, or to lambing range on private or public lands in sagebrush steppe on the Snake River Plain, home ranch, or farm. Shed-lambing for most project participants occurs from January to March. Turnout onto desert allotments occurs in early April, beginning the annual cycle anew. Following these spatiotemporal schedules, sheep bands passed through allotments (for which the operator held grazing permits or trailing rights) during the summer grazing season on public lands. Most bands were accompanied by a sheepherder and both herding and guardian dogs by day (Fig. 1), and by guardian dogs and sheepherders in the area at night. Sheepherders are the most experienced in day-to-day band management and are responsible for protecting the sheep from predators, keeping them watered and grazing, and managing their herding dogs, LGDs, horses, and equipment. Sheepherders also have the most direct influence on sheep and predator management in the field, and their ability to implement nonlethal methods on the ground in challenging terrain is critical to the project.

We hired and trained field technicians who worked directly with livestock producers and sheepherders. Their responsibilities were to detect and communicate information on the presence of wolves, analyze grazing routes in relation to wolf den and rendezvous sites, identify threats to sheep in specific locations, prescribe nonlethal livestock protection strategies, and proactively apply nonlethal deterrents to protect sheep, especially at night when the bands are on bedgrounds and most losses to predators occur. Sheep operations were offered project assistance only while grazing within the boundaries of the PA.

Sheep depredations were closely monitored by herders and reported to agency wildlife control agents within hours or days of each occurrence. The wildlife control agent would examine the carcasses or site where the losses occurred and determine cause of death, including the type of predator responsible for the depredation mortalities and injuries. It is possible that some minor sheep losses were undetected in both the protected and

Fig. 1.—Lava Lake herder and herding dogs among the sheep. Photo credit: Defenders of Wildlife.

unprotected areas, though the sheep are counted during shipping and at the end of the grazing season, which makes this scenario unlikely.

PA and NPA.—Our efforts to protect sheep occurred within the Big Wood River drainage with in the Ketchum Ranger District. The Big Wood River drainage runs primarily north to south from Galena Summit, southeast through a valley bounded by the Smoky, Boulder, and Pioneer Mountains, and past the towns of Ketchum, Sun Valley, Hailey, and Bellevue, Idaho; it is comprised almost entirely of lands managed by the United States Forest Service. We operated through 2 phases on the grazing allotments of the Big Wood River drainage within the Ketchum Ranger District of the Sawtooth National Forest in Blaine County, Idaho (Fig. 2). In Phase 1 (2008–2010), we protected sheep grazing in the PA covering approximately 598 km^2 (years 1–3). In Phase 2 (2011–2014), we expanded the PA to approximately 1,161 km^2.

The situation that precipitated our study and the formation of the project occurred in 2007 when a family of wolves known as the "Phantom Hill pack" killed sheep and LGDs on national forest land north of Ketchum. This particular area is part of the Sawtooth National Recreation Area and includes the historic Sawtooth Sheep Driveway along the Big Wood River. Under these circumstances—when sheep and LGDs are killed or injured—members of the pack or the entire depredating family of wolves normally would be killed by government officials in response to prevent more livestock depredations. In this situation, local residents strongly opposed killing the wolves, which were popular among wildlife watchers in the area. Nonlethal interventions were used instead, preventing further losses in this area through the end of the 2007 summer grazing season. This success led to the formation of a small coalition consisting of local sheep producers, county commissioners, a wildlife conservation organization, federal land managers, and state and federal biologists (see Supplementary Data SD1). This coalition became the Wood River Wolf Project.

During Phase 1, project personnel used nonlethal tools and methods on behalf of livestock operations to determine if these methods were effective at preventing wolf depredations in the PA. In Phase 2, we transitioned the responsibility of employing nonlethal tools to individual sheepherders, livestock managers, and sheep producers; project personnel served primarily as consultants who intermittently assisted in the field during situations of highly elevated depredation risk. Four major sheep producers participated in the project, which meant that during the summer grazing season each producer would have multiple bands of sheep that would enter and exit the PA at various times throughout the grazing season. None of the producers grazed sheep exclusively in the PA, but all had bands that spent a significant part of the summer grazing season there. When sheep were on Forest Service allotments, they were either in the PA, where we helped provide protection from wolf depredation, or they were in the NPA. The NPA consisted of all Forest Service grazing allotments that were near or adjacent to the PA; it also included nearby areas in which sheep from several of the participating producers grazed. These areas did not have project personnel providing additional protection or deterrent equipment. Both the PA and NPA were within the wolf management zone identified by Idaho Fish and Game as the Southern Mountains zone. The NPA included grazing allotment from the Ketchum Ranger District, Fairfield Ranger District, and the Sawtooth National Recreation Area. Comparing the number of sheep killed by wolves (see below) between the PA and NPA was the primary component of our evaluation of the project. We made concerted effort to include comparable grazing allotments between the PA and NPA, and, because we protected sheep almost entirely on Forest Service grazing allotments where sheep grazing primarily occurred, we excluded

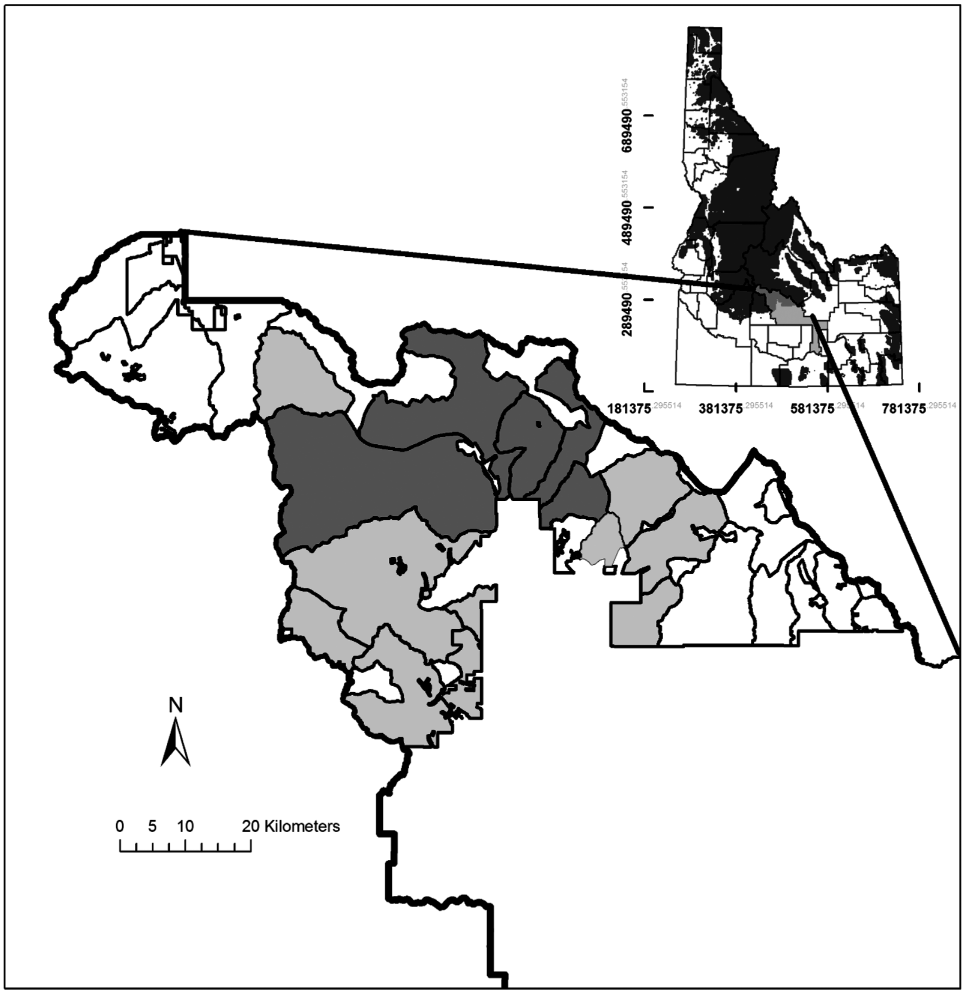

Fig. 2.—State of Idaho (inset), showing Blaine County (light gray) and National Forest Service land (dark gray). Northern portion of Blaine County is enlarged to show grazing allotments where Wood River Wolf Project was carried out during Phase 1 (darker gray) and Phase 2 (lighter gray and darker gray).

information on any sheep killed by wolves on private property or Bureau of Land Management land. Thus, our inference is restricted to grazing lands managed by the Forest Service, the primary grazing management agency within Blaine County.

Materials.—In order to weight the number of sheep killed in the PA and the NPA, we calculated the variable "sheep days." For this, we used data provided by the United States Forest Service on number of sheep on allotments and duration each grazing allotment was used by each of the 4 producers. Sheep days were calculated from Annual Operation Instructions, which are generated annually for every Forest Service allotment and which give details on the "Authorized Season of Use and Numbers" prior to the grazing season. We calculated sheep days for each allotment by multiplying the number of authorized sheep by the number of days of permitted use on the allotment. Annual Operation Instructions do not include numbers of lambs that may be present. For sheep bands consisting of both ewes and lambs, we used the Forest Service's method to calculate number of lambs, multiplying the authorized number of ewes by 1.5.

Data on the number of sheep killed came from USDA Wildlife Services. We used only those records for which it was designated as probable or confirmed that the predator was a wolf (and not those listed as "possible"). We considered data only for sheep, not cattle, because sheep are the primary livestock species grazed in the PA. Depredations within the PA that occurred prior to 1 July or after 15 October (the primary summer grazing season) were counted as being predations in the NPA. For each area, PA and NPA, we calculated a weighted number of sheep killed by summing the number of sheep killed each year and dividing the sum by the calculated number of sheep days. To make the value easier to handle, we multiplied it by 10^5. We graphed the cumulative number of sheep killed in each area over the 7-year period, measured the slope of the number of sheep killed per unit time, and used covariate analysis to test whether the slope in the PA differed from the slope in the NPA. We used program R version 3.0.1 (R Development Core Team 2013) and package "car" to perform the statistical test.

Impact of depredation.—Assessments of livestock loss and wolf depredations were compiled from official reports of depredation investigations (both federal and state) and from reimbursement claims for losses due to depredation. Number of wolf depredation events for the 4 primary producers grazing in the PA were determined from field investigation reports verified by Idaho USDA Wildlife Services from 1995 to 2010. These reports provide the official basis for annual reports by United States Fish and Wildlife Service on wolf management and livestock depredation in Idaho over the course of the 7-year demonstration project. The dates of these events were: 8 August 2008 (Blaine County, Baker Creek, 1 confirmed sheep); 4 July 2009 (Blaine County, 1 confirmed sheep); 10 August 2009 (Blaine County, Baker Creek, 12 confirmed sheep and 1 injured guard dog); 9 July 2010 (Blaine County, 1 confirmed sheep); 21 September 2010 (Blaine County, 4 confirmed sheep); 22 August 2011 (Blaine County, 1 probable sheep); 12 October 2011 (Blaine County, 1 probable sheep); 5 July 2012 (Blaine County, Lake Creek, 4 confirmed); 13 July 2014 (Blaine County, West Fork, 3 confirmed); 22 September 2014 (Blaine County, East Fork, 2 confirmed sheep) but these last 2 were likely bear depredations according to the herders who were present and our field manager.

Wolf presence.—Part of our effort involved trying to predict where wolves were on a daily and seasonal basis. Information on wolf presence in the PA was obtained from trained project field technicians, Idaho USDA Wildlife Services, Idaho Department of Fish and Game, reports from sheep producers and sheepherders, aerial and radiotelemetry monitoring, indirect and direct observation of wolf activity, and reports from hunters and recreationists. Wolf pack activity was documented in the PA annually from 2007 through 2014. During Phase 1, we used radiotelemetry to monitor radiocollared wolves from the Phantom Hill pack. In 2011, during Phase 2, we conducted surveys of howling, track and scat, and kill sites to identify pup and rendezvous sites for 3 separate packs whose territories overlapped the PA during the summer grazing season. In 2012, we conducted a field camera survey to document broader wolf activity in the county. Our field technicians set 18 cameras in territories of 3 primary packs and obtained images of multiple individual wolves in the range of each pack. Cameras were checked every 3–10 days in sheep-grazing areas but less frequently in other areas. In 2013, we again placed motion-sensing field cameras but only in areas where packs had denned or in areas that had been used for rendezvous sites in prior years. We documented 4 pups in the Hyndman pack along with at least 2 adults and captured images of wolves in the Baker Lake area. The Baker Lake field camera documented a sheep band and a wolf in the same location within a 48-h period. We documented wolf howling near sheep bands at night and physically chased wolves out of occupied sheep bedgrounds in 2009, 2011, and 2012. That same year, a 6-week-old wolf pup was captured from the Warm Springs pack on the western side of the PA. We documented multiple tracks from additional pups and an adult member in that pack after the capture of the pup. In summary, we documented consistent pack activity of ≥ 2 packs annually for 7 years, 3 packs during 5 of the 7 years, and 4 packs during 3 of the 7 years of the demonstration project.

Nonlethal deterrents.—It was our assumption that no single deterrent is adequate to deter wolves from livestock effectively over the entire grazing season. This was based on several hundred depredation reports and field examinations over decades by several of the coauthors. Instead of relying on a single or few deterrents, we tailored our use of adaptive nonlethal methods in the PA based on prior research on use of fladry, LGDs, and radioactivated guards conducted by Wildlife Services and the Natural Resource Conservation Service; survey information from livestock operators who experienced wolf depredations in Idaho, Montana, and Wyoming (Stone 2006, 2009); and adaptive protocols developed during an interagency workshop on livestock and wolf management at the 2006 Northern Rockies Wolf Conference. These methods included the use of increased numbers of LGDs per band in the post-denning season, reducing attractants such as livestock carcasses and diseased animals near sheep bands, penning bands at night when high-risk wolf encounters were likely, increased human presence near sheep bedgrounds, use of light and sound devices at night, predictions on wolf movements based on previous patterns, alternative grazing routes when feasible and necessary to avoid wolf rendezvous areas, and opportunistic hazing of wolves when necessary (see Table 1 for details regarding individual deterrents and methods).

Phase 1: 2008–2010.—During this initial phase, we increased human presence around sheep bands grazing through the PA, especially at night, and began to use nonlethal techniques when wolves were in close proximity to a band (Fig. 3; Table 1). Technicians were scheduled to accompany each band of sheep from dusk till dawn while sheep were in the PA. During this period, there were several radiocollared wolves from 2 or more known packs that ranged in and adjacent to the PA. We used radiotelemetry, conducted surveys on the presence of tracks, carcasses, and scat, and listened for howls to detect and monitor wolves. When wolves were detected or anticipated near sheep bands, field technicians and sheepherders deployed more aggressive nonlethal tools and techniques. These included increased nighttime camping near sheep bedgrounds, sound and light devices such as high beam flashlights, starter pistols, and air horns, or worked with agency and livestock managers to devise viable alternate grazing routes when possible to avoid encounters. We alternated use of scare devices to avoid habituating the wolves to any specific deterrent. We also discouraged producers and sheepherders from using LGDs in the spring near den or rendezvous sites to avoid conflicts caused by the natural aggression of wolves toward unfamiliar canids detected near their pups. We recorded several variables: number of sheep that grazed in the PA; dates and locations when wolves were detected in the vicinity of a band; dates and locations where sheep were killed; and whether a sheepherder was present at the time of the depredation. We also recorded which nonlethal tools were applied and, when discernable, how wolves responded to deterrents, the number of LGDs that were with each band, and the number of hours technicians were present in the field. These observations helped us determine when and where to deploy nonlethal deterrents in subsequent grazing seasons.

Phase 2: 2011–2014.—The Wood River Wolf Project was originally designed to be a 3-year feasibility study. However,

Table 1.—Nonlethal deterrent methods used to protect bands of sheep (*Ovis aries*) from gray wolves (*Canis lupus*) in the Wood River Wolf Project. Deterrents were used during the field season in the Protected Area of the study in Blaine County, Idaho.

Method	Description and application
Increased human presence	A team member guarded the band from dusk to dawn (when wolves are most active); the guard responded to threats from any predator (not just wolves) and used the nonlethal tool or tools deemed most effective. If no wolf activity was observed, the guard scanned the band and nearby area with the spotlight and radiotelemetry system several times during the night.
Increased number of livestock guardian dogs	Sheep producers and sheepherders were encouraged to assign ≥ 3 guardian dogs to each band for the season. Numbers were subject to change depending on potential conflict, with more dogs added when predator encounters were more likely. We recommended alternative deterrents in April through mid-June when wolf pups were restricted to a den or rendezvous site (when packs are highly defensive of pups).
Spotlight	A high-powered halogen spotlight was used to scan the band and surrounding hills and used frequently by night guards to check the band and deter potential predators.
Radioactivated guard box	A radiotelemetry device detected signals from radiocollars of collared wolves; collar frequency was programmed into the device. The box activated when the collar appeared within a preset range, setting off a variable series of lights and prerecorded alarm noises. Used only when radiocollared wolves were locally present and when access by motor vehicles was feasible. This device was rarely used because of difficulty setting it up, and few or no wolves in the Project Area were radiocollared.
Fladry and turbo-fladry	Fladry is a series of red or orange plastic flags (50 × 10 cm) sewn at 50-cm intervals on a nylon rope (0.2 cm in diameter), suspended 50 cm above the ground and supported on metal rebar posts spaced at 30-m intervals (Musiani and Visalberghi 2001; Musiani et al. 2003). For the later version ("turbo-fladry"), the rope was electrified; it was powered with a solar charger (Lance et al. 2010). Used when wolf activity and possibility of conflict was deemed to be high, where terrain was suitable, and the sheep producer was agreeable to its use. Sheep were driven into a fladry corral and enclosed for the night. This deterrent was used frequently in Phase 1 but not in Phase 2, when other effective and easier-to-use deterrents became available. (Turbo-fladry was kept available in case a situation needed more protection.)
Blank handgun	A .22 starter pistol that fired blanks into the air was used alone or with a klaxon when wolves were known to be near (detected visually, by wolf howls, or by strong telemetry readings). Also used when wolves were possibly near (determined by guard dogs barking consistently, wolf seen that day, weak telemetry readings, or recent depredation by wolves).
Klaxon	A loud air-horn was used alone or in conjunction with a blank handgun, under same conditions described for "blank handgun."
Radiotelemetry	Used for wolves fitted with radiocollars to give real-time indication of when these wolves were in the vicinity. The method permitted teams to respond with timely application of additional protection measures.
Flashing lights	Lighting devices were deployed near animals in danger of being attacked by predators at night. LED lights inside the device flashed irregularly, feigning human presence, with the intention of increasing a predator's sense of perceived risk. The devices were originally created for use in Australia to protect livestock from foxes and sold under the name Foxlights. Starting in 2014, devices were used at night near sheep bedgrounds to simulate human activity near the bands.

ranchers and Blaine County commissioners requested that the project be continued and extended to cover a larger area. In response, we adapted our methods to cover an expanded PA (increased from 598 to 1,161 km^2 by 2012) and advanced our yearly starting date from 15 July to 1 June, which allowed us to monitor wolves before sheep entered the PA. As a result of the areal expansion, the approximate number of adult sheep and lambs present seasonally in the PA increased from 10,000–12,000 to 20,000–22,000. However, by 2012, the few known radiocollared wolves in and around the PA had been killed by hunters or poachers, and we were unable to monitor wolves using radiotelemetry. By this time, the sheepherders had become more familiar with wolf behavior and more self-reliant in the use of nonlethal deterrents.

During Phase 2, the main responsibilities of field technicians changed from full-time intervention to providing a monitoring and support service. Technicians focused more attention on detecting wolf activity near sheep bands, with significant findings being promptly communicated to sheepherders. Wolf tracks, scat, and images were mapped in conjunction with grazing schedules to provide technicians with the information necessary to target and refine mitigation efforts, both spatially and temporally. Grazing allotments were surveyed for wolf activity in advance of sheep grazing. Technicians resumed providing direct field assistance including implementing additional protection measures when technicians suspected wolves were nearby. When feasible in late spring and early summer, sheepherders avoided wolf den and rendezvous sites where pups were raised. Results are presented as mean ± *SE* unless otherwise noted.

Results

It is estimated that annual losses from predator depredations accounted for 30–40% of all sheep mortality (United States Department of Agriculture – National Agricultural Statistics Service 2010), with wolves recently accounting for 4.1 % in 2011 and 4.4 % in 2012 of total confirmed and unconfirmed sheep losses statewide in Idaho (United States Department of Agriculture – National Agricultural Statistics Service 2013).

Fig. 3.—Lava Lake sheep in fladry. Photo credit: Defenders of Wildlife.

There was a total of 240,000 sheep in Idaho in 2011 and, according to producer estimates, wolves killed 1,300 statewide (or 1 out of every 184 sheep statewide—United States Department of Agriculture – National Agricultural Statistics Service 2013). In 2012, there were 235,000 sheep in Idaho, and wolves reportedly killed an estimated 1,400 (or 1 out of every 167) sheep statewide. The National Agricultural Statistics Service reports on self-reported estimates obtained from producer surveys, which primarily represent unverified losses. However, they are the only measure beyond minimum confirmed depredations reported by state or federal agencies that provide even a rough estimate of total livestock losses. Statewide, 576 wolves were killed in response to livestock depredations from 2008 through 2014 (United States Fish and Wildlife Service et al. 2016).

Over the 7-year project period, the 4 producers whose sheep we tracked had an annual mean of 576,000 ± 77,787 sheep days in the PA and 1,512,000 ± 157,876 sheep days in the NPA (Table 2). Wolves did not prey on sheep as frequently in the PA as in the NPA. The mean number of times they killed sheep was only 1.3 ± 0.3 times/year in the PA, but it was 9.4 ± 2.4 times/year in the NPA. Similarly, wolves killed far fewer sheep in the PA than the NPA; the mean number of sheep killed was 4.2 ± 1.8 sheep/year in the PA, but 44.8 ± 13.6 sheep/year in the NPA (Table 2). There were no known subsequent depredation losses following any single incident of depredation in the PA. Of a total of 11 incidents of sheep lost to wolves confirmed in the PA during the 7-year project period, 8 incidents involved only 1 or 2 sheep, and no single confirmed incident exceeded 12 sheep. After weighting the number of sheep killed by sheep days, the number of sheep killed was, on average, approximately 3.5 times greater in the NPA than in the PA. The slopes of the cumulative weighted number of sheep killed between the PA and NPA differed significantly (analysis of covariance: $F_{1,10} = 49.3$, $P < 0.001$; Fig. 4). The weighted number of sheep killed was lower in the NPA than in the PA during years 2011 and 2014. Some lethal wolf control occurred annually in the NPA; namely, during 2014, 2 packs were lethally removed by government wildlife managers. In comparison, no wolves were killed by wildlife managers or livestock operators in the PA from 2008 to 2014.

Discussion

Comparative results between the PA and NPA indicate that adaptive use of nonlethal methods reduced the number of sheep preyed on by wolves, reduced the need for lethal removal of wolves, and helped train and convince sheepherders that nonlethal methods can effectively manage wolf–sheep conflict. The presence of 1 or more field specialists assisting in monitoring and deterring wolves played a critical role in minimizing wolf-sheep interactions because they were able to select appropriate deterrents based on site-specific conditions at the time. Beyond addressing immediate risks, our field personnel and sheepherders (aided by increased numbers of guardian dogs for each band after wolf rearing periods in the spring) provided extra vigilance at night as well as being able to detect wolves when they were present near bands, and often accurately predicted movements in relationship to sheep-grazing routes. Field technicians taught herders how to use deterrent tools in ways that maximized their effectiveness while minimizing the potential for wolves to habituate to the deterrents. Most importantly, together technicians and herders concluded that without human presence, especially at night, wolves and other predators tended to prey more heavily on the sheep bands.

Table 2.—Depredation of sheep (*Ovis aries*) by gray wolves (*Canis lupus*) in the Protected Area and Nonprotected Area of the Wood River Wolf Project, Blaine County, Idaho. In the Protected Area, only nonlethal methods were used to prevent depredation. Sheep days = number of sheep in the area × number of days, as described in the text. Weighted number of sheep killed = (sheep killed/sheep day) × 10^5.

Year	Protected Area				Nonprotected Area			
	Number of wolf attacks	Number of sheep killed	Sheep days	Weighted no. of sheep killed	Number of wolf attacks	Number of sheep killed	Sheep days	Weighted no. of sheep killed
2008	1	1	233,305	0.43	14	55	1,547,825	3.55
2009	1	13	512,188	2.54	14	96	1,929,082	4.98
2010	2	5	534,061	0.94	15	64	1,987,172	3.22
2011	2	2	524,475	0.38	2	5	1,605,951	0.31
2012	1	4	821,638	0.49	11	49	1,435,615	3.41
2013	0	0	707,740	0.00	9	44	905,028	4.86
2014	2	5	695,220	0.72	1	1	1,175,560	0.09
Total	9	30	4,028,627	5.49	66	314	10,586,233	20.42

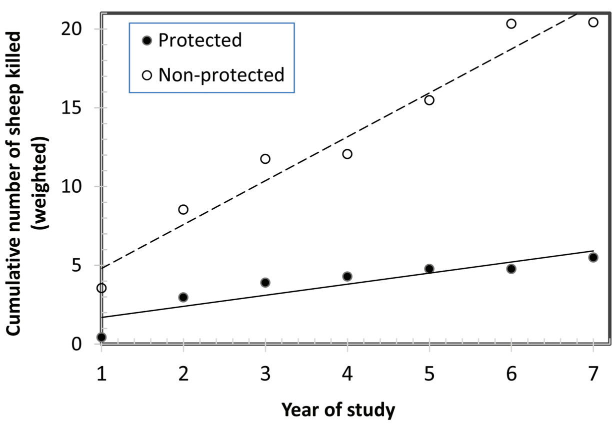

Fig. 4.—Killing of sheep (*Ovis aries*) by wolves (*Canis lupus*) in Protected and Nonprotected Areas in public grazing allotments in Blaine County, Idaho, as shown by cumulative weighted number of sheep killed in each year of the study. Lines indicate regression of killings on year.

The Wood River Wolf Project was designed as a case study to determine if nonlethal methods could be applied effectively at the large landscape level to reduce losses of sheep and wolves. It was not designed primarily as a scientific study, but rather, as a management intervention that allowed some opportunity for collecting and analyzing data to assess the effectiveness of nonlethal wolf management strategies. Our research was limited by lack of a control site or sites where nonlethal measures were not used, and thus our results and conclusion should be interpreted cautiously. We acknowledge that this work was a case study and that more rigorous research would be helpful in confirming (or disproving) our findings. However, we find it encouraging that upon completion of our work, livestock producers from our study area took the initiative to continue the project, which indicates that they were convinced our methods are useful for protecting sheep. Every annual grazing season that the nonlethal methods continue to demonstrate success is evidence that nonlethal methods can be highly effective on large-scale grazing operations.

There are other issues that this paper does not address, including the impact of lethal wolf control and wolf hunting in the NPA, which had implications for this study but are not easily measured. For example, several wolves were killed annually in the NPA and, in some years, this represented most known members of resident packs; this was the case in 2014 when 2 packs in the NPA were lethally removed because of depredation on livestock (Idaho Department of Fish and Game and Nez Perce Tribe 2014). Hunters also trapped, snared, and shot more wolves in the NPA than in the PA where public trapping and snaring were not allowed. In 2011 and 2014, the weighted number of sheep lost to wolves was lower in the NPA than the PA, but this may have been due to lethal control of wolf packs, which would have temporarily resulted in fewer livestock depredations until new wolves dispersed into the NPA. Sheep grazing, and perhaps wolf behavior, in both areas were also affected by occasional wildfires in the PA and NPA.

Shepherding is an ancient practice, but the use of a variety of new nonlethal deterrent tools and techniques and the ability to understand wolf behavior and movement can be novel for sheepherders who have never dealt with wolves. It is likely that there was a strong educational component during both phases of the project. The transfer of knowledge relating to the most effective use of nonlethal tools and techniques enabled the sheepherders to become increasingly proficient in their implementation. This is important because nearly all sheep producers grazing on public lands employ sheepherders who manage their bands on a daily basis. Familiarizing livestock producers and sheepherders with novel techniques and gaining their participation in protecting sheep from wolves is critical for successfully reducing sheep depredations.

An important hurdle for the project was gaining the support of producers to implement nonlethal methods in a fashion that maximized their effectiveness. All but 1 livestock operator in the Wood River Wolf Project initially expressed resistance to changes in their operations. Some producers relied on a few nonlethal measures, which they repetitively applied without regard to wolf presence. Wolves and other predators are adaptable and thus may habituate to a deterrent if they are exposed to it too frequently or for too long a period. Adaptively rotating methods and carefully timing their application can reduce such habituation (Shivik and Martin 2000; Shivik 2006). If wolves become habituated to a deterrent, that method is no longer a deterrent. The loss of nonlethal tools increases the probability that lethal control will be employed as the alternative management option.

Testing nonlethal measures in a field situation leads to questions regarding the best protocols to use, when and where to use them, and concerns that the costs may be greater than ranchers could afford to adopt. This is a valid consideration because these methods may require additional labor and equipment depending on the size and type of operation. For example, project costs ranged from $22,000 to $48,000 annually, with technician contract labor and field transportation representing more than 85% of the total annual costs. In 2014, project costs for a seasonal field contractor and equipment were $20,250, during which time 20,120 sheep grazed in the PA. Split among the 4 producers, this represents an additional cost of $5,063 per year per producer (or approximately $1.00 per sheep).

Some livestock operators who attended training workshops or outreach events sponsored by the Wood River Wolf Project expressed concern that nonlethal methods may be unreliable. Some of these livestock operators also reported attempting a nonlethal method, then experiencing wolf depredations, and returning to lethal control as a more trusted strategy (Stone 2006). For example, 1 Idaho sheep producer reported using fladry barriers to protect a band of sheep, but he continued to lose sheep to wolves. While discussing this incident, it was discovered that the fladry was incorrectly installed too high above the ground, allowing wolves to walk under it and continue to kill sheep. Another farmer reported playing loud music in his barn every night for several weeks to keep predators at bay. When we examined the site, we discovered that a large horse carcass had been left for more than a month next to the barn before a wolf killed a ram in a pen located next to the barn. Livestock carcasses are attractants known to draw wolves from miles away (R. Morgan, Oregon Department of Fish and Wildlife, pers. comm.).

The most important aspect of nonlethal deterrent strategies to protect livestock from wolf depredation is correctly implementing effective measures before losses occur. The project employed a site evaluation process (see Supplementary Data SD2) that helped livestock managers understand and address risks, but this process still requires technical assistance to ensure that best management methods are implemented. The need for a consistent applicator, such as an experienced field technician, to be present is currently a major limitation to nonlethal predator management. Furthermore, as noted previously, not every situation allows for proper use of nonlethal wolf and sheep management methods.

Nonlethal measures were effective at reducing or preventing sheep losses to wolves across a large landscape during the summer and early fall grazing periods. The most common factor that led to confirmed depredations by wolves on sheep in the PA was not having active deterrents in place, or not having enough of them, when undocumented wolves appeared at sheep bedding grounds at night. During the annual evaluation process, the project steering committee observed that the greatest protection against chronic or heavy livestock losses to wolves reliably came from using this adaptive strategy—implementing tools and methods based on season, terrain, proximity to wolves, and availability of access. The steering committee based their evaluation on the repeated success of the intervention methods in protecting sheep from immediate threat of wolf depredation.

It is believed that stable wolf packs are easier to manage with nonlethal deterrents than unstable packs because stable packs tend to hold and remain in their own established territory, which discourages new wolves from entering the area (Smith 2005; Mech and Boitani 2007). Knowledge of the behavior of stable packs helps guide nonlethal strategies, such as avoiding traditional den sites in the spring, and it increases the odds of successfully avoiding depredations. Packs that are disrupted or eliminated by lethal control leave vacant territory that other wolves soon fill (Mech and Boitani 2007). In the absence of adequate nonlethal strategies for livestock protection, loss of livestock and wolves is more likely to occur. These nonlethal strategies should include adequate livestock husbandry, as noted by Wallach et al. (this issue), because livestock that are weakened by disease, bad weather, complications with birthing, or other problems due to poor husbandry are more susceptible to depredation by native predators.

While some livestock owners in Idaho report an increased interest in nonlethal methods (Stone 2009), strict adherence to nonlethal methods remains uncommon and largely unsupported by funding or assistance in implementation. Specifically, in Idaho, there is no permanent state or federal program to protect livestock from depredations using nonlethal wolf deterrents that is comparable to programs for lethal control. However, several western states have recently adopted programs to encourage the use of nonlethal methods and provide funding assistance to livestock producers to implement these strategies. Although they use models different from the Wood River Wolf Project, the states of Oregon and Washington provide technical assistance and even require, in certain circumstances, that livestock producers use reasonable nonlethal deterrence methods (Wiles et al. 2011; Oregon Department of Fish and Wildlife 2016).

Having a system for documenting and evaluating the use of these methods and predator responses would help in developing more reliable protocols for the use of nonlethal methods. Our site evaluation system (see Supplementary Data SD2) is an example of the type of information needed to help assess the long-term use of these strategies. Overall, a combined approach incorporating consistent human presence at night, wolf monitoring to determine and help predict pack movements, and appropriate deterrents carefully applied has effectively reduced the loss of sheep and wolves in the Wood River Wolf Project's PA. This model may be applicable in other settings and contexts to reduce the loss of livestock and lethal control of native predators that share the landscape.

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Supplementary Data

Supplementary Data SD1.—Social framework of the Wood River Wolf Project.

Supplementary Data SD2.—The Wood River Wolf Project site evaluation form.

Literature Cited

Arthur, L. M. 1981. Coyote control: the public response. Journal of Range Management 34:14–15.

Bangs, E., et al. 2006. Non-lethal and lethal tools to manage wolf-livestock conflict in the northwestern United States. Pp. 7–16 in Proceedings of the 22nd Vertebrate Pest Conference (R. M. Timm and J. M. O'Brien, eds.). University of California, Davis.

Baker, P. J., L. Boitani, S. Harris, G. Saunders, and P. C. White. 2008. Terrestrial carnivores and human food production: impact and management. Mammal Review 38:123–166.

Bradley E. H., et al. 2015. Effects of wolf removal on livestock depredation recurrence and wolf recovery in Montana, Idaho, and Wyoming. The Journal of Wildlife Management 79:1337–1346.

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

Bruskotter, J. T., J. J. Vaske, and R. H. Schmidt. 2009. Social and cognitive correlates of Utah residents' acceptance of the lethal control of wolves. Human Dimensions of Wildlife 14:119–132.

Duda, M. D., et al. 2008. Public opinion on hunting and wildlife management in Washington. Produced for Washington Department of Fish and Game by Responsive Management, Harrisonburg, Virginia.

Fritts, S. H., W. J. Paul, L. D. Mech, and D. P. Scott. 1992. Trends and management of wolf-livestock conflicts in Minnesota. United States Fish and Wildlife Service, Resource Publication 181.

Gehring, T. M., B. E. Kohn, J. L. Gehring, and E. M. Anderson. 2003. Limits to plasticity in gray wolf, *Canis lupus*, pack structure: conservation implications for recovering populations. Canadian Field Naturalist 117:419–423.

Gehring, T. M., K. C. Vercauteren, M. L. Provost, and A. C. Cellar. 2010. Utility of livestock-protection dogs for deterring wildlife from cattle farms. CSIRO PUBLISHING. Wildlife Research 37:715–721. http://www.publish.csiro.au/WR/WR10023. Accessed 21 October 2016.

Harper, E., W. J. Paul, D. L. Mech, and S. Weisberg. 2008. Effectiveness of lethal, directed wolf-depredation control in Minnesota. Journal of Wildlife Management 72:778–784.

Holsman, R., N. Kaner, and J. Petchenik. 2014. Public attitudes towards wolves and wolf management in Wisconsin. Wisconsin Department of Natural Resources, Madison. http://dnr.wi.gov/topic/wildlifehabitat/wolf/documents/wolfattitudesurveyreport-draft.pdf. Accessed 14 September 2015.

Idaho Department of Fish and Game and Nez Perce Tribe. 2008. Idaho wolf monitoring progress report. Idaho Department of Fish and Game, Boise; Nez Perce Tribe Wolf Recovery Project, Lapwai, Idaho.

Idaho Department of Fish and Game and Nez Perce Tribe. 2009. Idaho wolf monitoring progress report. Idaho Department of Fish and Game, Boise; Nez Perce Tribe Wolf Recovery Project, Lapwai, Idaho.

Idaho Department of Fish and Game and Nez Perce Tribe. 2010. Idaho wolf monitoring progress report. Idaho Department of Fish and Game, Boise; Nez Perce Tribe Wolf Recovery Project, Lapwai, Idaho.

Idaho Department of Fish and Game and Nez Perce Tribe. 2011. Idaho wolf monitoring progress report. Idaho Department of Fish and Game, Boise; Nez Perce Tribe Wolf Recovery Project, Lapwai, Idaho.

Idaho Department of Fish and Game and Nez Perce Tribe. 2012. Idaho wolf monitoring progress report. Idaho Department of Fish and Game, Boise; Nez Perce Tribe Wolf Recovery Project, Lapwai, Idaho.

Idaho Department of Fish and Game and Nez Perce Tribe. 2013. Idaho wolf monitoring progress report. Idaho Department of Fish and Game, Boise; Nez Perce Tribe Wolf Recovery Project, Lapwai, Idaho.

Idaho Department of Fish and Game and Nez Perce Tribe. 2014. Idaho wolf monitoring progress report. Idaho Department of Fish and Game, Boise; Nez Perce Tribe Wolf Recovery Project, Lapwai, Idaho.

Idaho Sheep Loss Report. 2013. Idaho sheep inventory down 2 percent from previous year.https://www.nass.usda.gov/Statistics_by_State/Idaho/Publications/Livestock_Press_Releases/2012/SheepJan2013NR.pdf. Accessed 14 September 2015.

Lopez, B. 1978. Of wolves and men. Scribner, New York.

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

Mech, L. D., and L. Boitani. 2003. Wolves: behavior, ecology, and conservation. University of Chicago Press, Chicago, Illinois.

Mech, L. D., and L. Boitani. 2007. Wolves: behavior, ecology, and conservation. University of Chicago Press, Chicago, Illinois.

Mech, L. D., E. K. Harper, T. J. Meier, and W. J. Paul. 2000. Assessing factors that may predispose Minnesota farms to wolf depredations on cattle. Wildlife Society Bulletin 28:623–629.

Musiani, M., et al. 2003. Wolf depredation trends and the use of fladry barriers to protect livestock in western North America. Conservation Biology 17:1538–1547.

Musiani, M., T. Muhly, C. C. Gates, C. Callaghan, M. E. Smith, and E. Tosoni. 2005. Seasonality and reoccurrence of depredation and wolf control in western North America. Wildlife Society Bulletin 33:876–887.

Oregon Department of Fish and Wildlife. 2016. Oregon wolf conservation and management—2015 annual report. Pp. 11–13. http://dfw.state.or.us/Wolves/docs/oregon_wolf_program/2015_Annual_Wolf_Report_3-18-16_FINAL.pdf. Accessed 19 September 2016.

R Development Core Team. 2013. A language and environment for statistical computing, version 3.0.1. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org. Accessed 15 January 2016.

Reiter, D. K., M. W. Brunson, and R. H. Schmidt. 1999. Public attitudes toward wildlife damage management and policy. The Wildlife Society Bulletin 27:746–758.

Rimbey, N. L., A. Torell, S. Kane, J. Gustanski, J. Kennedy, and D. Scarsella. 2014. Idaho private rangeland grazing—lease arrangements. University of Idaho, Idaho College of Agricultural and Life Sciences, Research Bulletin 185, Moscow. http://www.idl.idaho.gov/leasing/grazing/rate/2014-ui-bulletin-185-id-private-rangeland-grazing-lease-arrangements.pdf. Accessed 11 September 2015.

Russell, B. 2015. New state wolf board has spent $140K so far to kill 31 wolves. The Spokesman-Review. http://www.spokesman.com/blogs/boise/2015/feb/03/new-state-wolf-board-has-spent-140k-so-far-kill-31-wolves/. Accessed 10 September 2015.

Shelton, M. 2004. Predation and livestock production-perspective and overview. Sheep and Goat Research Journal 19:2–6. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1012&context=icwdmsheepgoat. Accessed 20 September 2016.

Shivik, J. A. 2006. Tools for the edge: what's new for conserving carnivores? BioScience 56:253–259.

Shivik, J. A., and D. J. Martin. 2000. Aversive and disruptive stimulus applications for managing predation. Pp. 111–119 in Wildlife Damage Management Conferences – Proceedings. University of Nebraska–Lincoln, Lincoln. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1019&context=icwdm_wdmconfproc. Accessed 7 July 2016.

Slagle, K., J. T. Bruskotter, A. S. Singh, and R. H. Schmidt. This issue. Attitudes toward predator control in the United States: 1995 and 2014. Journal of Mammalogy.

Smallidge, S. T., H. Halbritter, N. K. Ashcroft, and J. C. Boren. 2008. Review of livestock management practices to minimize livestock depredation by wolves: applicability to the Southwest. Department of Extension Animal Sciences and Natural Resources, New Mexico State University, Las Cruces, New Mexico.

Smith, D. W. 2005. Ten years of Yellowstone wolves. Yellowstone Science 13:7–33.

Stone, S. A. 2006. Wolf conservation and conflicts in the USA Northern Rockies. M.A. thesis, Prescott College, Prescott, Arizona.

Stone, S. A. 2009. Compensation and non-lethal deterrent programs: building tolerance for wolf restoration in the Rockies. Pp. 141–158 in A new era for wolves and people: wolf recovery, human attitudes, and policy (M. Musiani, L. Boitani, P. C. Paquet, eds.). University of Calgary Press, Calgary, Alberta, Canada.

United States Department of Agriculture – National Agricultural Statistics Service. 2010. Sheep and goats death loss. Washington, D.C. http://usda.mannlib.cornell.edu/usda/current/sgdl/sgdl-05-27-2010.pdf. Accessed 14 September 2015.

United States Department of Agriculture – National Agricultural Statistics Service. 2013. Idaho APHIS Wildlife Services sheep report 2011–2012. Idaho Wool Growers Bulletin.

United States Fish and Wildlife Service, et al. 2012. Northern Rocky Mountain wolf recovery program 2011 interagency annual report (M. D. Jimenez and S. A. Becker, eds.). United States Fish and Wildlife Service, Ecological Services, Helena, Montana.

United States Fish and Wildlife Service, et al. 2014. Northern Rocky Mountain wolf recovery program 2013 interagency annual report (M. D. Jimenez and S. A. Becker, eds.). United States Fish and Wildlife Service, Ecological Services, Helena, Montana.

United States Fish and Wildlife Service, et al. 2016. Northern Rocky Mountain wolf recovery program 2015 interagency annual report (M. D. Jimenez and S. A. Becker, eds.). United States Fish and Wildlife Service, Ecological Services, Helena, Montana. Table 7a. https://www.fws.gov/mountain-prairie/es/species/mammals/wolf/2016/FINAL_Table7a_Dep-RecArea_2015%20(1).pdf.

Wallach, A. D., D. Ramp, and A. J. O'Neill. This issue. Cattle mortality on a predator friendly station in central Australia. Journal of Mammalogy.

Wiles, G. J., H. L. Allen, and G. E. Hayes. 2011. Wolf conservation and management plan for Washington. Washington Department of Fish and Wildlife, Olympia.

Young, S. P., and E. A. Goldman. 1944. The wolves of North America, Vol. 1. American Wildlife Institute, Washington, D.C.

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