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Evaluation of wolf-livestock conflicts and management in the northwestern United States

Elizabeth H. Bradley
The University of Montana

AN EVALUATION OF WOLF-LIVESTOCK CONFLICTS AND MANAGEMENT IN THE NORTHWESTERN UNITED STATES

by

Elizabeth H. Bradley

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Approved by:

Chairperson

Dean, Graduate School

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Abstract:

Wolf (*Canis lupus*) populations are recovering in Montana, Idaho, and Wyoming as a result of dispersal from Canada and reintroduction into Yellowstone National Park and Central Idaho. Wolves sometimes kill livestock, causing much controversy and concern over how best to manage livestock depredations while promoting wolf recovery. In this thesis, I evaluated wolf-livestock conflicts and management methods used by the U.S. Fish and Wildlife Service from 1987-2002.

First, I examined the effects of wolf removal (from lethal control or translocation) on reducing livestock depredations. After partial or complete wolf pack removal, depredations usually ceased for the remainder of the given grazing season. However, most packs that were partially removed (68%) depredated again within the year. Rate of recolonization of territories where entire packs were removed ($n = 10$) was high (70%) and most recolonizations (86%) occurred within a year of the previous pack's removal. Most recolonized packs depredated (86%). Packs that had alphas removed were no less likely to depredate again within the year than packs with non-alphas removed.

Second, I examined wolf pack establishment, depredations, survival, and homing behavior of translocated wolves to evaluate the effectiveness of translocation as a non-lethal method. Most translocated wolves (67%) failed to establish or join a pack after release and 27% resumed depredating. Still, 8 new packs were established as a result of translocations. Translocated wolves had lower annual survival (0.60) than other radio-collared wolves (0.73). Mortality of translocated wolves was primarily human-caused with government control comprising the largest source of mortality. Release area was the most important factor related to wolf survival. Wolves showed a strong tendency to home.

Third, I examined factors related to wolf depredation of cattle in fenced pastures. I compared 34 pastures that had experienced depredations to 62 nearby pastures that had not experienced depredations in Montana and Idaho. Pastures where depredations occurred were more likely to have elk (*Cervus elaphus*) present, were larger in size, had more cattle, and grazed cattle further from residences than pastures without depredations. Greater vegetation cover, closer proximity to wolf dens, and physical vulnerability of cattle were also likely important factors.

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I dedicate this thesis to the memory of Mike Fairchild, who inspired me to pursue wolf research and encouraged me to apply to graduate school at the University of Montana.

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Chapter 1. Introduction

Wolves (*Canis lupus*) sometimes kill livestock, dogs, and other domestic animals and therefore have come into conflict with humans where their range overlaps areas of human settlement and agriculture (Mech 1995, Fritts et al. 2003). Conflicts with livestock were partly responsible for the heavy persecution of wolves in the contiguous United States which led to their near complete extirpation by the 1930s (Young and Goldman 1944, Curnow 1969). Wolves in Eurasia experienced similar persecution resulting in the fragmentation and reduction of populations across their former range (Boitani 1995). Wolf populations are currently recovering in many areas (Mech 1995, Bangs et al. 1998) and livestock depredations have concurrently increased in areas where recovery areas overlap agricultural lands [Fritts et al. 1992, U.S. Fish and Wildlife Service (USFWS) 2003].

In the contiguous United States, gray wolves were given legal protection under the Endangered Species Act (ESA) of 1973. As part of the recovery plan mandated by the ESA, 3 areas were identified in the northwestern U.S. as suitable recovery areas: northwestern Montana, central Idaho, and the greater Yellowstone area (USFWS 1987). Recovery via dispersal of wolves from Canada began in northwestern Montana in the early 1980s (Ream et al. 1991) and was supported as part of the recovery plan. Wolves were reintroduced in 1995 and 1996 to central Idaho and Yellowstone National Park (Bangs and Fritts 1996, Fritts et al. 1997).

Wolf depredation on livestock has caused considerable controversy and concern. Many livestock interest groups and livestock producers were strongly opposed to wolf recovery (Fritts et al. 1995). Livestock depredations have occurred less than predicted but the issue has remained controversial (Bangs et al. 1998, Bangs et al. 2004). Although wolf depredation on livestock composes only a fraction of overall livestock mortality taken by the livestock industry each year, some individual producers may incur significant losses (Bangs et al. 2004).

Wolf recovery goals called for at least 10 breeding pairs of wolves in each of the 3 recovery areas for 3 consecutive years for delisting to occur (USFWS 1987). This has since been changed to a goal of 30 breeding pairs total across the 3 areas for 3 consecutive years (E. E. Bangs, USFWS, personal communication). Wolves reached this goal at the end of 2002 (USFWS 2003*a*) and were subsequently downlisted to threatened status in 2003 (USFWS 2003*b*). The USFWS is currently working toward eventual delisting and transfer of wolf management to the states.

I initiated this research, in cooperation with the USFWS, Yellowstone Wolf Project, Nez Perce Tribe, Defenders of Wildlife, Turner Endangered Species Fund, and National Fish and Wildlife Foundation, to evaluate various aspects of wolf-livestock conflicts and management in Montana, Idaho, and Wyoming, under direction of the USFWS from 1987-2002. The purpose of this project was to provide information that could be useful for improving management of wolf-livestock conflicts by both current federal and future state wolf managers. My thesis includes 3 chapters related to the 3 main management methods used by the USFWS to mitigate wolf-livestock conflicts: lethal control of depredating wolves, translocation of depredating wolves, and non-lethal preventative methods. My objectives were: 1) to evaluate lethal control and translocation as methods to mitigate livestock damage, and 2) to determine factors related to wolf-depredated cattle pastures that could lend insight into development of non-lethal preventative methods. Each of these chapters was written in manuscript style for submission to peer-reviewed journals. Therefore, there is some redundancy within chapters, especially in regards to background information.

In Chapter 2, I evaluated the effects of removing wolves (by lethal control or translocation) on reducing livestock depredations. I looked both at cases of partial wolf pack removal and complete pack removal. For partial pack removal, I evaluated whether and to what extent the remaining pack continued depredating after removal. I also examined whether removal of alpha individuals or the remaining pack size affected whether depredations persisted. For cases of complete pack removal, I examined whether territories were reoccupied, how quickly recolonizations occurred, and whether depredations resumed.

In Chapter 3, I evaluated the fate of translocated wolves. I assessed depredations, pack establishment, survival, and homing behavior of translocated wolves to evaluate the effectiveness of translocation as a non-lethal method to mitigate livestock damage. I considered how results differed within each of the 3 wolf recovery areas and discussed how this method may be improved.

In Chapter 4, I present data collected from cattle ranches in Montana and Idaho in areas where wolf depredations had occurred within fenced pastures. I compared various factors related to pastures that experienced depredations to nearby pastures that did not experience depredations. I conducted univariate tests and Classification Tree Analysis to determine what single and combination of variables best described pastures where depredations occurred. My goal was to determine whether such information could lend insight into development of non-lethal preventative methods.

I have included all conclusions and management recommendations within each chapter. All chapters represent a collaborative effort; therefore I have used 'we' instead of 'I' throughout. However, I am responsible for all data analysis and writing and take full responsibility for any mistakes within this thesis.

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Chapter 2. Effects of Wolf Removal on Livestock Depredation in Montana, Idaho, and Wyoming

Abstract: Methods used to mitigate wolf (*Canis lupus*) depredation on livestock in Montana, Idaho, and Wyoming have largely consisted of removing individuals from depredating packs, either by lethal or non-lethal (translocation) means. We examined the effects of partial and complete removal of wolf packs on the persistence of livestock depredations. From 1987-2002, an average of 30% of all packs with livestock in their territory (22% of all packs with or without livestock) were confirmed to have depredated per year; of these, 63% underwent removal of ≥1 individual. Most packs (68%) depredated again within a year of undergoing partial pack removal though intervals between livestock depredations increased by an average of 270 days after removal actions compared to before. Removing alpha individuals appeared no more effective than removing non-alphas in reducing depredations within the year. Packs that underwent partial removal contributed similar numbers of breeding pairs (defined as an adult male and female raising ≥2 pups through 31 December) toward recovery goals as depredating packs that did not undergo removal but fewer breeding pairs than non-depredating packs. Rate of recolonization of territories where entire packs were removed (n = 10) was high (70%) and most recolonizations (86%) occurred within a year of the previous pack's removal. Most recolonized packs depredated (86%); intervals between the last depredation of the removed pack and first depredation of the recolonized pack averaged 276 days. Almost all depredations involved ≥1 previously affected livestock producer. We suggest chronic depredations result more from factors inherent in locality rather than

individual pack behavior. Our findings may be useful for managers seeking to balance objectives of wolf recovery and depredation mitigation.

INTRODUCTION

Depredation on livestock has put wolves (*Canis lupus*) in conflict with humans for centuries and continues to be a major issue facing their persistence and recovery in livestock production areas around the world (Mech 1995, Fritts et al. 2003). Wolves primarily prey on wild ungulates in North America (Tompa 1983, Bjorge and Gunson 1983, Fritts et al. 2003) but livestock are preyed upon frequently by wolves in some areas of Europe and Asia, especially where wild ungulates are scarce or absent (Jhala and Giles 1991, Vos 2000, Fritts et al. 2003). Although conflict intensity varies, intolerance is widespread and effective mitigation of conflicts is therefore a critical component of management programs where wolves and humans coexist.

In Montana, Idaho, and Wyoming, where wolves are protected under the Endangered Species Act (ESA), managing depredation on livestock has been a central focus of wolf recovery efforts (Bangs et al. 1998). Defenders of Wildlife, a non-profit organization, compensate livestock producers for confirmed wolf depredations (Fischer 1989) but effective methods that directly reduce depredations are also necessary. Dealing with conflicts in such a way as to not impede population growth of wolves has been important in attempts to encourage local tolerance while working toward recovery goals.

A variety of non-lethal preventative tools have been used in response to conflicts, but few have been adequately tested and none have proven completely effective (Cluff and Murray 1995, Bangs and Shivik 2001). Removal of depredating wolves, either by lethal or non-lethal means, has therefore been the primary method used in response to livestock depredations (Bangs et al. 1995, Bangs et al. 1998). Wolves are removed incrementally until depredations at least temporarily stop, but in some chronic situations, entire packs are eliminated. As the wolf population in Montana, Idaho, and Wyoming expands, lethal control is increasingly used because translocation of depredating wolves is more expensive and there are fewer adequate areas in which to release wolves (Chapter 3). Lethal control is considered a necessary component of wolf management (Mech 1995) but is controversial with much of the public (Cluff and Murray 1995, Reiter et al. 1999).

Determining the effectiveness of wolf removal at reducing livestock depredations has proven difficult, although some level of relief does appear to result (Tompa 1983, Bjorge and Gunson 1983, 1985, Fritts et al. 1992). Limitations of working within a management framework have made controlled experiments infeasible, and therefore evaluations of available data are an important means of helping improve existing knowledge. Wolves were downlisted from endangered to threatened status under the ESA in 2003 (United States Fish and Wildlife Service [USFWS] 2003*a*). Delisting and transfer of responsibilities from federal to state management could occur soon. Knowledge gained under federal management will therefore be beneficial to state managers as well as other wolf management programs that seek to balance objectives of recovery and depredation mitigation. We examined data on livestock depredations and wolf removal conducted under direction of the USFWS from 1987-2002. Our primary objective was to evaluate the effects of partial and complete pack removal on persistence of depredations. For partial pack removals, we considered the effects of alpha removal and remaining pack size in reducing depredations and the relative contribution of these packs to recovery goals.

WOLF RECOVERY AREAS

Montana, Idaho, and Wyoming are divided into 3 recovery areas for wolf management purposes (USFWS 1987): central Idaho, the Greater Yellowstone area (GYA), and northwest Montana (Figure 1). Wolves were reintroduced into central Idaho and Yellowstone National Park (GYA) in 1995 and 1996 (Bangs and Fritts 1996, Fritts et al. 1997) and were managed as a non-essential experimental population under section 10(j) of the Endangered Species Act (ESA) to allow for more flexibility in managing conflicts with livestock (USFWS 1994). Wolves naturally recolonized northwest Montana via dispersal from Canada (Ream et al. 1991) and had full protection under the ESA as an endangered species during this study.

As part of recovery planning, core recovery areas were identified within each of the 3 areas (Figure 1) that provided some protected habitat for wolves. Each core area included remote areas without livestock: parts of the central Idaho wilderness complex, Yellowstone National Park in the GYA, and Glacier National Park and parts of the Bob Marshall wilderness complex in northwest Montana (USFWS 1987). Wolves settled within core areas in the central Idaho and GYA recovery areas more than in northwest Montana (Figure 1, USFWS 1999).

The wolf population grew rapidly in the central Idaho and GYA areas after reintroduction (Fritts et al. 2001) but more slowly in northwest Montana. At the end of 2002, at least 663 wolves inhabited the 3 recovery areas: 284 in central Idaho, 271 in the

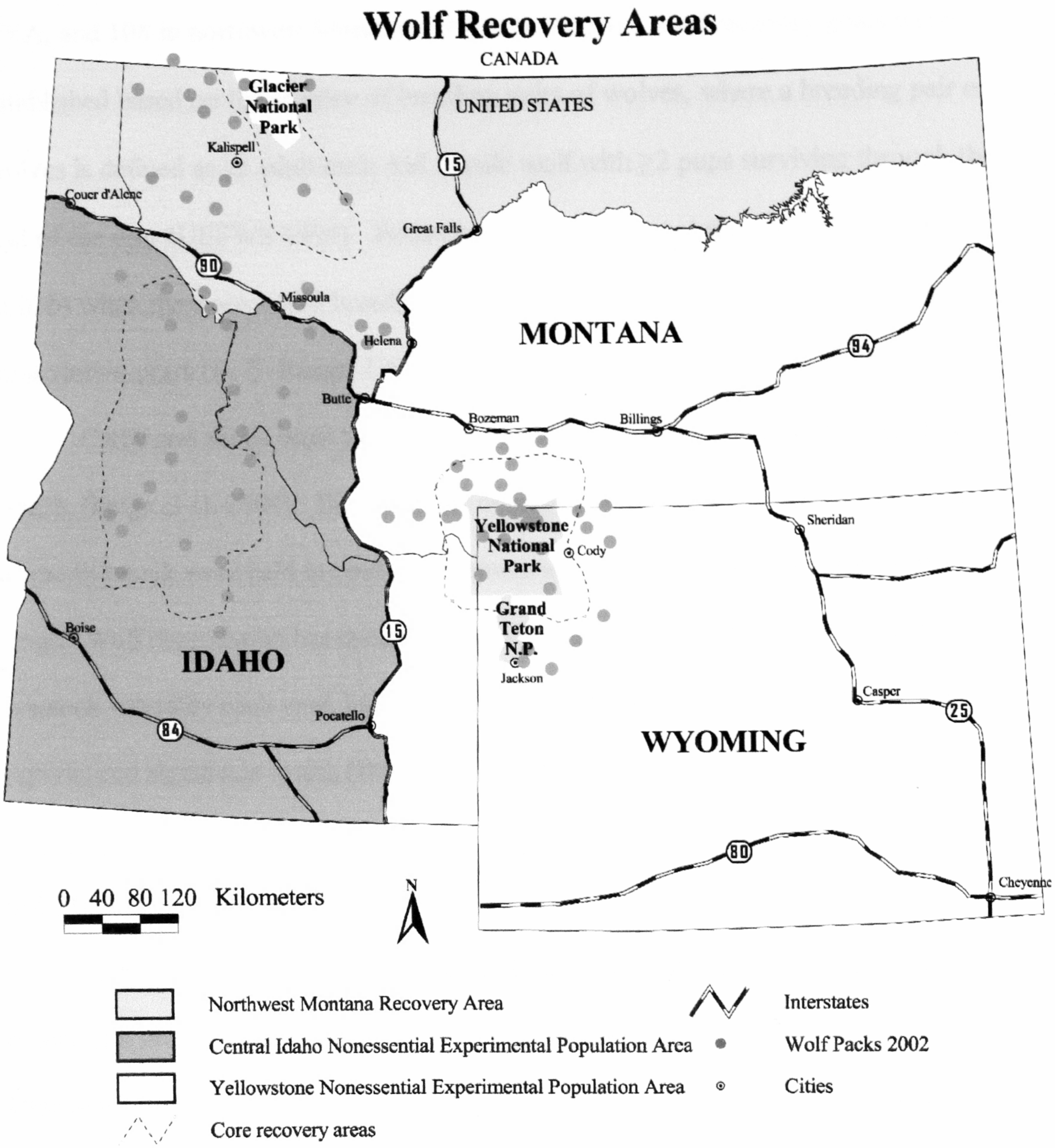

Figure 1. Wolf pack locations in Montana, Idaho, and Wyoming, 2002.

GYA, and 108 in northwest Montana (USFWS 2003*b*). Wolf recovery goals were established based on the number of breeding pairs of wolves, where a breeding pair of wolves is defined as an adult male and female wolf with $\geq$2 pups surviving through the end of the year (USFWS 1994). Recovery goals were met at the end of 2002 (USFWS 2003*b*) when there were $\geq$30 breeding pairs of wolves across the 3 recovery areas for 3 consecutive years (E. E. Bangs, USFWS, personal communication).

Cattle and sheep were the primary livestock preyed upon by wolves (USFWS 2003*b*, Bangs et al. 2004). Depredations occurred on both private and public lands, where livestock were held in confined pastures and where they were grazed on the open range. Wolf depredation has composed only a small fraction of the total causes of livestock mortality each year, but in some cases, individual livestock producers have experienced significant losses (Bangs et al. 1995, 1998, 2004).

METHODS

Data were compiled on all confirmed wolf depredations on livestock and subsequent removal events in Montana, Idaho, and Wyoming from 1987-2002. Depredations were confirmed by United States Department of Agriculture Wildlife Services (WS) personnel using standard protocols (Roy and Dorrance 1976, Paul and Gipson 1994) and represent minimum numbers of livestock killed. Other depredations may not have been reported or found, or evidence was insufficient to confirm (Bangs et al. 1998, Oakleaf et al. 2003). Initial depredation events were often followed by an increase in monitoring (USFWS 1999), which likely helped increase detection of further depredations. Depredation and removal data were compiled on established packs only, which we defined as groups of $\geq$2 wolves with established territories. Wolf packs were radio-collared either before or during control operations. Pack involvement in depredations was determined by proximity of the pack based on radio-telemetry locations or documented return of pack members to the depredation site, or both.

Wolf removal was authorized by the USFWS only when wolf involvement was confirmed (USFWS 1999). Lethal removal and translocation were the primary methods used to remove wolves from packs although, in a few cases, wolves were placed permanently in captivity. Selection of removal methods was based on the number of breeding pairs of wolves present and availability of suitable release sites (USFWS 1999). Lethal removal was primarily conducted by WS personnel, under direction of the USFWS, and usually consisted of trapping or aerial gunning. Landowners in the experimental areas could legally shoot wolves they caught in the act of killing their livestock, and in some cases, were issued shoot-on-site permits (USFWS 1994) that allowed a given number of wolves to be shot by a permittee on their private land within a certain time period. Wolves that were translocated were darted by aircraft or trapped, transported, then either hard (immediately) or soft (temporarily held in enclosure) released in areas with abundant wild ungulates without livestock or other wolf packs. Wolves that returned to depredation sites were not counted as being removed. We define a removal action as a block of $\geq$1 wolf removal events in response to single or multiple depredations that usually occurred within the same area and grazing season.

We measured success of partial wolf pack removal in two ways: first, by whether packs depredated again within a year of the removal action, and second, by determining the extent to which intervals between depredations were longer after removal actions than before. Intervals between depredations were calculated, in days, before and after removal actions. "Before" intervals were calculated as the number of days between the two depredations immediately preceding the first removal event. "After" intervals were calculated as the number of days between the depredation immediately preceding the last removal event and the following depredation. Days were subtracted from depredation intervals when livestock were seasonally absent from wolves' territories. For cases where packs stopped depredating after the removal action, we truncated "after" depredation intervals at 31 December 2002. Packs that chronically depredated and were eventually completely removed were always partially removed first. We included these cases in our analysis of partial wolf pack removal actions by considering the removal action before the final removal event occurred to avoid biasing the sample toward less chronic situations. "Before" and "after" intervals were compared using the Wilcoxon signed-rank test.

Depredation incidents vary seasonally; we report the total number of cattle and sheep depredation events by month. Cessation of depredations may be due to seasonal changes in availability of livestock. Therefore, we compared "before" and "after" depredation intervals by first weighting days in intervals by the probability of a depredation occurring during that season to determine whether results differed compared to unweighted results. Seasons were defined as 3 periods based on general livestock management trends in the study area: 1) Spring (calving/lambing): 16 February – 31 May (105 days), 2) Summer (open range grazing): 1 June – 31 October (153 days), and 3) Winter: 1 November – 15 February (107 days). The following formula was used to weight days within each season: [No. of days of depredation interval in season / total days in season (total proportion of depredation events that have occurred in that season between 1987-2002)] × 365. In this way, days that fell within seasons that had a higher proportion of depredation events were weighted as being longer than those that fell during seasons with a lower proportion of depredation events. We compared "before" and "after" intervals using the Wilcoxon signed-rank test, as above.

We examined whether removal of alpha wolves and the size of the pack after removal had any effect on subsequent depredations after removal actions. Alpha determination was based on physical characteristics that indicated breeding, but alpha males were sometimes difficult to identify. Therefore, cases where we knew at least one alpha was removed were grouped with cases where both alphas were removed. We used a 2x2 contingency table and chi-square to compare packs that had alphas removed to packs that had non-alphas removed in relation to whether those packs depredated or not within a year of the removal action. Pack sizes were estimated based on aerial or ground observations, and in some cases, snow tracking. We compared size of wolf packs after removal to whether or not those packs depredated again within a year but sample size was too small to permit statistical analysis.

Managing depredation on livestock was conducted in such a way as to take the minimal action necessary to mitigate conflicts so as to maximize the number of packs that could potentially contribute breeding pairs toward wolf recovery goals (USFWS 1999). We examined the contribution to recovery goals of wolf packs that had been partially removed and then compared this to 1) packs that had depredated but had not undergone removal; and 2) packs that had not depredated. Breeding pair status was only considered for packs from 1995-2002, because criteria for breeding pairs were not defined until 1994 and prior data was therefore unavailable. For packs that underwent removal, recovery goal contribution was considered for the year following removal. Packs were tallied across years to determine the number of packs counted as breeding pairs. Groups were compared using a 2x2 contingency table and chi-square test.

We evaluated complete removal of wolf packs by examining the reoccupancy of territories where wolves had been removed and subsequent depredation by new packs. For territories that were reoccupied, we examined whether these new packs depredated and if so, if the same livestock producers or ranches incurred depredations. We calculated the time between the last depredation of the pack that was removed and the first depredation by the pack that recolonized. We compared depredation intervals after complete removal of packs to those after partial removal of packs using the Mann-Whitney U test and report P-values. We compared these results with weighted results, as above.

RESULTS

For the sixteen-year period, an average of 22% of all packs depredated annually. Almost half (49%) of all packs had livestock in their territory but did not depredate. Only 29% of all packs did not have livestock within their territory, such as those in Yellowstone National Park and the central Idaho wilderness (Table 1). Some packs depredated in some years and not in others, and therefore fell into alternate categories in different years. For those packs with livestock within their territories, an average of 30% depredated annually.

Table 1. Wolf packs in areas with and without livestock in their territories in Montana, Idaho, and Wyoming, 1987-2002. Packs with livestock in their territories are broken out by whether they killed livestock (depredated) or did not kill livestock (non-depredated). Percentages of packs that underwent removal[a] are shown in parentheses.

Year	Packs with livestock		Packs without livestock	Total
	Depredated	Non-depredated		
1987-93	5 (100%)	24		29 (17%)
1994	2 (50%)	7		9 (11%)
1995	1 (100%)	9	5	15 (7%)
1996	5 (80%)	18	6	29 (14%)
1997	7 (86%)	13	10	30 (20%)
1998	6 (50%)	18	12	36 (8%)
1999	10 (70%)	14	13	37 (19%)
2000	13 (54%)	22	17	52 (13%)
2001	13 (62%)	31	21	65 (12%)
2002	20 (50%)	32	27	79 (13%)
Total	82 (63%)	188	111	381 (14%)
% of Total	22%	49%	29%	

[a] Removal consisted of lethal control or translocation of depredating wolves.

Of those packs that depredated, 63% underwent removal (Table 1). From 1987-2002, 148 wolves were lethally removed for livestock depredation, 131 of which were from established packs. Some were shot by ranchers caught in the act of killing livestock (n = 4) or with shoot-on-site permits (n = 3) but most (n = 141) were killed by government officials (USFWS 2003*b*). Translocations involved 88 wolves (Chapter 3), some of which were relocated multiple times. Partial pack removal actions varied in length from 1 to 89 days ($\bar{x}$ = 13) and averaged 1.5 removal events per action. Number of wolves removed per action ranged from 1 to 14 ($\bar{x}$ = 3.2). Twenty-one packs were involved in 34 removal actions: 6 packs in the central Idaho recovery area (11 removal actions), 7 packs in the GYA (9 removal actions), and 8 packs in northwest Montana (14 removal actions). Eleven packs underwent 1 removal action; the remainder underwent 2 (7 packs) or 3 removal actions (3 packs). Packs depredated again within a year in 23 (68%) of the 34 removal actions. Through 2002, only 3 of the 21 packs had not been implicated in another confirmed depredation after 1 removal action. In northwest Montana and the GYA, 57% and 56% of removal actions were followed by packs depredating again within a year, respectively, compared to 91% in central Idaho.

More depredations occurred during the summer grazing period (n = 170, 65%) than spring (n = 64, 24%) or winter (n = 29, 11%). Cattle depredations peaked in August and September whereas sheep depredations were fairly consistent from June through October (Figure 2). We compared depredation intervals before and after only 22 of the 34 removal actions because 12 were preceded by only 1 depredation event and therefore we could not calculate a "before" interval for comparison. Two cases were truncated at 31 December 2002 because depredations had not occurred before this date. Depredation intervals before and after removal actions differed (Wilcoxon signed-rank test, Z = -2.52, P = 0.012) and increased, on average, by 270 days after ($\bar{x}$ = 360, SD = 432, range = 4-1617) compared to before removal actions ($\bar{x}$ = 90, SD = 127, range = 1-479). Results changed little by weighting days by the seasonal probability of depredation occurrence (Wilcoxon signed-rank test, Z = -2.42, P = 0.016). We found depredation intervals were 282 weighted days longer on average after ($\bar{x}$ = 379, SD = 491, range = 3-1997) than before removal actions ($\bar{x}$ = 97, SD = 127, range = 1-467).

Alpha removal occurred in 17 of 34 removal actions and appeared to have no effect on whether a pack depredated again within a year of the removal action (χ^2_1 = 0.134, P = 0.71). Depredations occurred within a year for 12 packs (71%) with $\geq$1 alpha removed compared to 11 packs (65%) with non-alphas removed. Effects of pack size on subsequent depredations were even less clear. Packs with 1 wolf remaining or $\geq$10

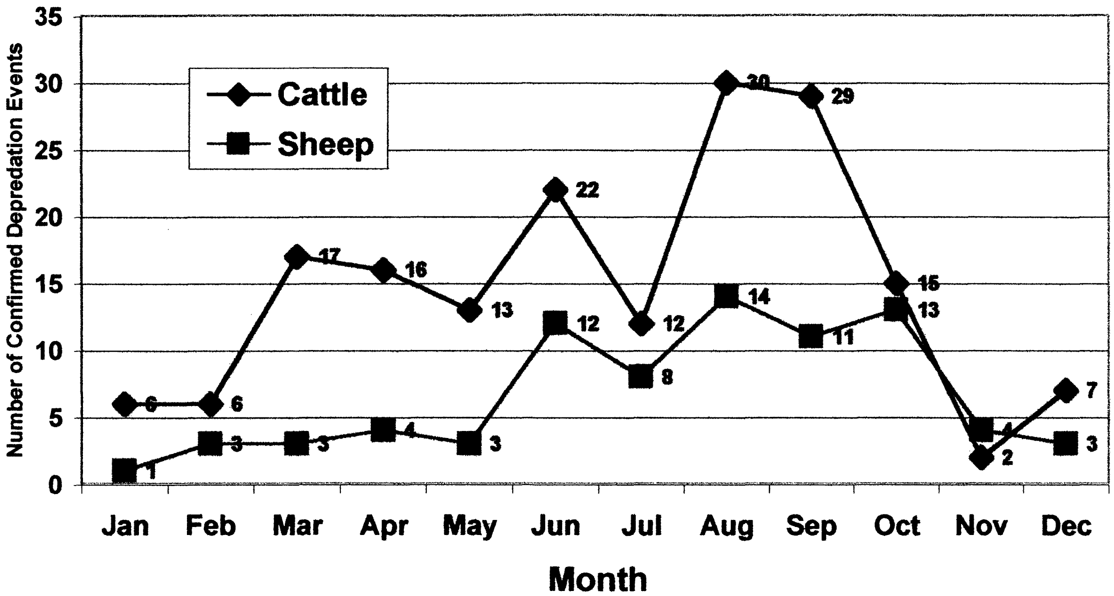

Figure 2. Confirmed cattle and sheep depredation events by wolves in Montana, Idaho, and Wyoming, 1987-2002.

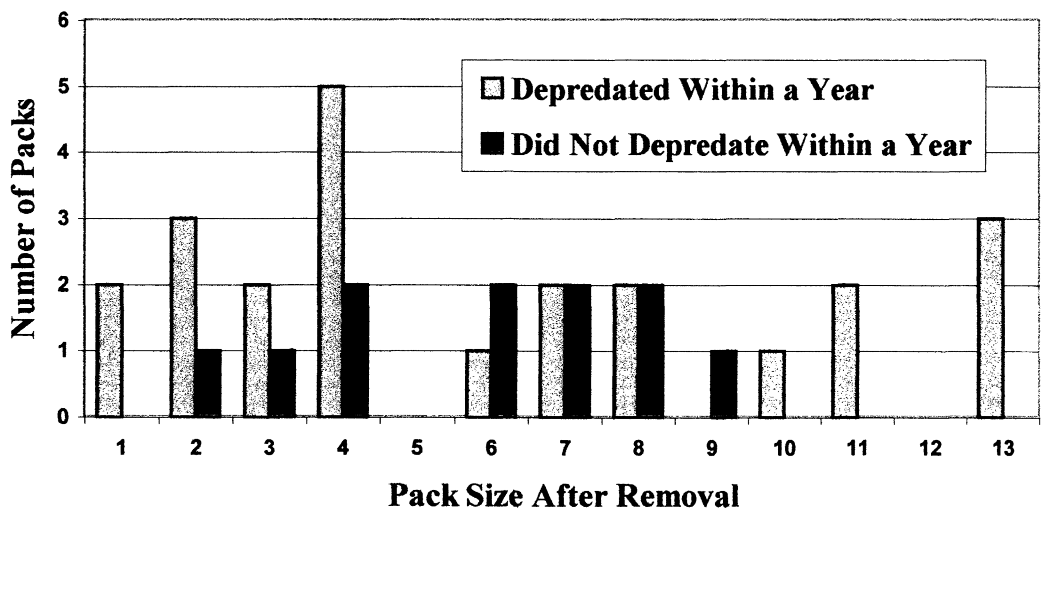

Figure 3. Wolf packs that depredated livestock within a year after part of the pack was removed

wolves all depredated again within a year of the removal action but sample sizes were small (Figure 3).

Across years from 1995-2002, 9 of 25 (36%) packs that underwent removal contributed to recovery goals compared to 11 of 23 (48%) packs that depredated but did not undergo removal and 139 of 241 (58%) non-depredating packs (Table 2). Contribution to recovery goals was similar between packs that underwent removal and packs that depredated but did not undergo removal ($\chi^2_1 = 0.689$, $P = 0.41$). A greater difference existed between packs that underwent removal and non-depredating packs ($\chi^2_1 = 4.31$, $P = 0.038$).

Table 2. Wolf packs counted as breeding pairs[a] toward recovery goals across years in northwest Montana, the Greater Yellowstone, and central Idaho recovery areas, 1995-2002. Wolf packs are broken out by whether they depredated livestock and underwent removal[b], depredated livestock but did not undergo removal, or did not depredate.

	Depredated		Non-Depredated
Recovery Area	Removal[c]	No Removal	
Northwest Montana			
Breeding Pairs	5	5	32
Not Breeding Pairs	2	5	34
Greater Yellowstone			
Breeding Pairs	3	4	57
Not Breeding Pairs	7	3	26
Central Idaho			
Breeding Pairs	1	2	50
Not Breeding Pairs	7	4	42
Total[d]	25 (36%)	23 (48%)	241 (58%)

[a] An adult male and female and ≥ 2 pups must survive through 31 December to be counted as a breeding pair.
[b] Removal consisted of lethal control or translocation of depredating wolves.
[c] Packs that underwent removal were considered for breeding pair status for year of breeding season following removal.
[d] Includes, in parentheses, the percentage of total packs in each category that contributed breeding pairs toward recovery goals.

Ten packs were entirely removed: 8 packs were intentionally removed and 2 disbanded after multiple removal events. Recolonization of vacant habitat occurred in 7 (70%) of these instances. In one case, 1 pack reoccupied portions of both territories of 2 removed packs. Six recolonizations occurred within 1 year of the previous packs' removal and 1 occurred 5 years later. Six recolonized packs killed livestock, five of which depredated ≥1 livestock producer or ranch previously affected. Days between the last depredation of the pack that was removed and first confirmed depredation of the pack that recolonized ranged from 99 to 383 days ($\bar{x}$ = 276, SD = 110, *n* = 5) for all cases but one where recolonization occurred after 5 years and which was an extreme outlier (3190 days). Excluding this outlier, depredation intervals after entire pack removal were similar (Z = -0.4, P = 0.69) to those after partial pack removal ($\bar{x}$ = 324, SD = 364, *n* = 34). We found similar results after weighting by seasonal probability of depredation occurrence (Z = -0.78, P = 0.44). Weighted depredation intervals after entire pack removal ($\bar{x}$ = 262, SD = 108) were similar to those after partial pack removal ($\bar{x}$ = 325, SD = 424).

DISCUSSION

We found that 22% of all packs and 30% of packs that had livestock within their territory depredated each year but this may be a conservative estimate because not all depredations are found or reported. Oakleaf et al. (2003) found that detection rates for cattle killed by wolves on a grazing allotment in central Idaho could be 1 for every 8 cattle killed. Detection may be more accurate when cattle are held in fenced pastures where they can be more closely monitored (Chapter 4). Little is known regarding the extent to which livestock depredations may be detected but unreported although, potential for compensation payments creates an incentive for livestock producers to report kills. Overall, on a yearly basis, most packs exposed to livestock did not appear to depredate, which is consistent with findings from Minnesota (Fritts and Mech 1981, Fritts 1982, Fritts et al. 1992), Wisconsin (Treves et al. 2002), and British Columbia (Tompa 1983). However, we did not consider the level of exposure to livestock. Density and distribution of livestock within packs' territories likely plays a role in depredation risk and a closer examination in this regard would be useful.

Most packs (63%) that depredated underwent removal and 68% depredated again within a year. Even though most packs exposed to livestock did not appear to depredate on a yearly basis, most packs, once they depredated, tended to repeat this behavior whether within a year or not. Removal actions in the central Idaho recovery area had a higher percentage of depredation recurrence for packs than the other 2 recovery areas. Idaho has not had more depredations than other areas (USFWS 2003*b*) but rather, packs that depredated exhibited more chronic behavior. Reasons for this are unclear but may include effects of topography and seasonal ungulate movements that may draw wolves into proximity with cattle during calving time. A large number of sheep overlapping wolves' territories in the summer months, specifically in the Stanley Basin area of central Idaho, relative to other areas may also contribute to persistent problems.

Wolf removal in western Canada appeared to help reduce depredations, at least to some degree (Tompa 1983, Bjorge and Gunson 1983, 1985). In Minnesota, depredations appeared to decrease locally at some farms following removals (Fritts 1982, Fritts et al. 1992). Evaluation methods largely consisted of looking at repeated depredation occurrence at farms or conflict areas to determine problem persistence. In British

Columbia, depredations recurred in conflict areas within a year of lethal control in 66% of cases (calculated from Tompa 1983). In Minnesota, 34% of farms where wolves were removed had another depredation within a year (Fritts et al. 1992). Our results are more consistent with British Columbia, perhaps due to depredations having been considered over a broader area, rather than at individual farms. However, our methods differed from both studies in that we followed depredation histories of individual wolf packs.

We also found similarities to western Canada in seasonal cattle losses, with peak depredations occurring in late summer (Dorrance 1982, Gunson 1983, Tompa 1983). Alternatively, most cattle depredations in Minnesota and Wisconsin occur in late spring and early summer (Fritts et al. 1992, Treves et al. 2002). Sheep losses typically occur in July and August in Minnesota (Fritts et al. 1992) whereas we found them to be more evenly distributed through the summer and early fall, similar to Alberta (Gunson 1983). Consistency of our results to those in western Canada may be due to regional similarities in topography, livestock management practices, and seasonality in wild ungulate movements.

Most removal actions ended when depredations appeared to subside, therefore we were not surprised to find depredation intervals longer after removal actions than before. More importantly, depredation intervals were long enough, on average, after removal actions to last the remainder of the grazing season and this may have helped temporarily reduce losses and assuage local tension and animosity, even though most packs still depredated again within the year. Whether wolf removal was a causative factor in reducing depredations in the short-term is unknown. Though we took seasonality into account, we could not control for other factors that could have affected depredations, such as increased human presence and vigilance, and use of preventative methods. Short-term reductions in livestock losses were also found in British Columbia (Tompa 1983) but depredations were just as likely to continue at depredated farms that underwent wolf removal in Minnesota as those that had not (Fritts et al. 1992). We had no adequate control for comparison, so the possibility remains that depredations would have ceased in the short-term without any action being taken. We also cannot rule out the possibility of undetected depredations that may have resulted in overestimation of length of depredation intervals, but increased monitoring after initial depredations likely helped increase detection.

Discerning whether entire packs or individuals are involved in depredations is difficult (Fritts et al. 1992), but is important for managers deciding which animals should be removed. Problem individuals, if they exist, may still be difficult to target (Linnell et al. 1999). Efforts were sometimes made to identify and target offending individuals by trapping or shooting wolves that returned to livestock carcasses. Radio-collared individuals found close to depredation sites were targeted because their presence could be verified, but this may have resulted in a bias towards removal of radio-collared wolves. Adults and yearlings were preferentially removed over pups because pups are not offending individuals and this was found to be more effective in Minnesota (Fritts et al. 1992). Otherwise, unless individual offenders could be identified, removal was generally non-selective. Alpha individuals, as dominant leaders of a pack, are known to often lead hunts on wild prey (Mech 1988) and therefore could reasonably be expected to lead livestock depredations (Fritts et al. 1992). We found no evidence however, that removing alphas curbed depredations any more than removing non-alphas, which was consistent with findings in Minnesota (Fritts et al. 1992).

We expected that pack size would also be an important factor in persistence of depredations. Larger packs may be more likely to depredate again sooner simply because higher energy requirements require more frequent predation or, pressure to feed more individuals may lead packs to prey on an easier food source, such as livestock. Also, if certain individuals from the pack were responsible for the depredations, it is less likely, by chance, that they were removed. We found that all packs of $\geq$10 wolves ($n = 6$) depredated again within a year. But five of these packs were from Idaho, three of which also depredated again when their pack sizes were smaller. Because packs in Idaho proved to be more chronic depredators, it is possible that regional factors could be a greater factor than pack size. Sample size was too small for results to be conclusive. Cases where 1 individual remained ($n = 2$) also resulted in depredations within a year. Loss of cooperative hunting structure may lead individuals to target easier prey. But individuals are more difficult to detect than packs and situations could have existed where 1 individual remained but did not depredate, and therefore was not detected (available data could be biased towards situations where depredations occurred). These questions should be examined more thoroughly in the future when more data are available.

The lower contribution to recovery goals of packs that underwent removal could be the result of at least 2 factors. The most obvious explanation is that packs that have lost 1 or more breeding individual are less likely to reproduce the following season. However, packs that underwent removal and contributed to recovery goals (36%) did not differ greatly from packs that depredated but did not undergo removal (48%). The larger difference existed between packs that underwent removal and non-depredating packs. Non-depredating packs include those in national parks and wilderness areas where livestock were absent and there was less potential for contact with humans. Habitat differences, affecting potential for contact with humans and livestock, may therefore play a larger role in reproductive success than effects of removal.

Bjorge and Gunson (1985) found that in Alberta, vacant wolf territories were filled within 1-2 years. We also found that most territories were recolonized and that most recolonizations occurred within a year. Two packs whose territories were not reoccupied inhabited the Rocky Mountain Front area of western Montana and were removed in 1987 and 1997. After the removal of these packs, immigrant wolves have appeared but depredated and were subsequently removed before new packs were established. Six of seven recolonized packs depredated, suggesting that not only partial removal of packs but complete removal of packs are temporary solutions to livestock depredation. Interestingly, almost all recolonized packs depredated previously affected livestock producers. In all cases, other producers' livestock were available within the packs' territories. We suggest that chronic depredation behavior is not an attribute of individual packs as much as it may be related to factors inherent in these locations that present a higher risk for livestock conflicts. Factors increasing the risk of wolf predation on livestock are little understood but could include topography, vegetation cover (Bjorge 1983, Chapter 4), density of natural prey (Gunson 1983, Treves et al. 2004, Chapter 4), proximity of livestock to the forest/agricultural edge (Gunson 1983, Tompa 1983, Bjorge and Gunson 1985), density and distribution of livestock (Fritts et al. 1992, Mech et al.

2000, Treves et al. 2004, Chapter 4), presence of livestock carrion (Fritts 1982, Fritts et al. 1992, Mech et al. 2000), physical vulnerability of livestock, and proximity of ranches to wolf dens (Chapter 4).

Recolonizations may occur more quickly if other wolf packs live nearby. The recolonization event that took 5 years occurred in northwest Montana in the early 1990s when the wolf population was smaller. This situation is therefore less comparable to recolonizations that occurred further along in recovery when the wolf population was larger. The rapid growth and expansion of the wolf population after reintroduction is a likely factor in explaining the swift reoccupation of these territories. Predicting the probability of recolonization in given areas based on population dynamics may be helpful in determining the most effective wolf removal strategies. Complete removal of packs may be a better strategy, for example, where probability of recolonization is low or unlikely to occur soon.

MANAGEMENT RECOMMENDATIONS

Most depredations appear to stop for at least the remainder of a given grazing season after partial or complete pack removal providing valuable short-term relief. However, whether wolf removal is the direct cause of such reductions in depredations is unknown and warrants further research. The wolf population in Montana, Idaho, and Wyoming, has grown rapidly despite the use of lethal removal and packs from which wolves were removed contributed similar numbers of breeding pairs toward wolf recovery goals as did other non-depredating packs exposed to livestock. Consequently, lethal removal will likely continue to be used as a management tool, at least, until more effective non-lethal methods can be implemented. Efforts should therefore focus on improving the efficiency and cost-effectiveness of lethal removal.

We suggest that selectively removing alpha individuals is no better a strategy than removing non-alphas and being less selective in this regard may lower costs. The need for government control may be somewhat reduced by issuing more shoot-on-site permits to landowners, when practical. Such on-site removal may have an advantage over aerial removal (which often occurs off-site) in that other pack members may learn avoidance of an area, potentially decreasing the need for further lethal removal. This may have the combined benefit of reducing government costs, empowering local people, and potentially creating more selective removal if individuals return to depredation sites.

Most packs still depredate again within a year after partial pack removal; therefore other methods need to be explored for mitigating conflicts. Chronic depredation situations that warrant complete removal of packs are particularly challenging because in areas where likelihood of recolonization is high, conflicts may always occur unless methods are found for excluding or at least minimizing the influx of immigrant wolves. Continual removal of wolf packs in these chronic areas is likely to be expensive and controversial. Developing better long-term strategies in these areas is therefore important.

Research should continue to be encouraged toward development of non-lethal preventative tools. Many are currently being tested and developed with the help of the National Wildlife Research Center and non-governmental organizations (Bangs and Shivik 2001, Shivik et al. 2003). Determining what factors predispose some areas to depredation more than others may help in the development of new preventative methods.

A long-term strategy may include emphasis on identification of these factors and prioritization of applicable resources toward use in chronic depredation areas, which has already occurred in some areas, especially Idaho (Shivik and Martin 2001, USFWS 2003*b*). When livestock are grazed on open range in the summer months and often spread widely, depredation problems are more difficult to mitigate than when livestock are contained. As a long-term strategy, some non-governmental organizations are attempting to retire grazing allotments that have proven to be centers of chronic conflict with wolves and other predators.

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Chapter 3. Evaluating Wolf Translocation as a Non-lethal Method to Reduce Livestock Conflicts in the Northwestern United States

Abstract: Successful non-lethal management of livestock depredations is important for conserving carnivores that are rare or endangered. Large carnivores that kill livestock are commonly translocated away from conflict sites in attempts to non-lethally mitigate conflicts. In the northwestern United States, wolves (*Canis lupus*) have sometimes been translocated with the objective of reducing livestock conflicts while promoting wolf restoration. We assessed depredations, pack establishment, survival, and homing behavior of 88 translocated wolves to determine the effectiveness of this method in our region and consider how it may be improved. Over one-quarter of translocated wolves depredated again after release. Most translocated wolves (67%) never established or joined a pack, although 8 new packs resulted from translocations. Translocated wolves had lower annual survival (0.60) than other radio-collared wolves (0.73) with government removal composing the largest source of mortality. In northwest Montana, where most wolves have settled in human-populated areas with livestock, survival of translocated wolves was lowest (0.41) and more wolves proportionally failed to establish packs (83%) after release. Annual survival of translocated wolves was highest in central Idaho (0.71) and more wolves proportionally established packs (44%) than in the other 2 recovery areas. Translocated wolves showed a strong homing tendency; most of those that failed to home still showed directional movement toward capture sites. Wolves that successfully homed back to capture sites were more likely to be adults, hard-released rather than soft-released, and translocated shorter distances than other wolves that did not home. We conclude that success of translocations varied and was most affected by the

area in which wolves were released. We suggest managers choosing to translocate wolves or other large carnivores consider soft-releasing individuals in family groups when feasible as this may decrease homing behavior and increase release site fidelity.

INTRODUCTION

The effort to conserve and restore large carnivore populations around the world has proven a struggle between conflicting human interests (Treves & Karanth 2003). Some people value large carnivores inherently, for cultural or symbolic reasons (Weber and Rabinowitz 1996). Large carnivores, however, have been persecuted for centuries because of human safety concerns, competition for wild game, and for preying on livestock. Many species have declined or been extirpated (Fuller 1995), creating concerns for their extinction and resulting implications to ecosystems. Top predators are recognized by conservationists as strong interactors within ecological communities whereby their removal or recovery may cause cascading effects at various trophic levels (Estes 1996, Smith et al. 2003). However, efforts to restore large carnivores are often confronted with the same concerns that precipitated initial declines. Strategies for balancing carnivore conservation with human concerns are therefore crucial for successful restoration and subsequent management.

Large carnivores prey on domestic livestock in many areas of the world (Kaczensky 1999, Fritts et al. 2003, Treves & Karanth 2003), causing considerable economic concern. Depredating animals are generally not tolerated and are often killed. Finding non-lethal ways to mitigate livestock damage is a common goal of those that seek to conserve carnivores (Mishra et al. 2003, Ogada et al. 2003, Shivik et al. 2003).

Some techniques, such as compensation programs, have proven widely applicable to offset monetary losses. Still, effective non-lethal methods are needed that directly reduce conflicts.

Translocation has been used for decades as a method to mitigate livestock damage caused by large carnivores such as brown and black bears (Armistead et al. 1994, Blanchard and Knight 1995), wild felids (Rabinowitz 1986, Ruth et al. 1998), and wolves (Fritts et al. 1984, 1985, Bangs et al. 1995). Translocations may also serve to augment or establish new populations (Griffith et al. 1989, Wolf et al. 1996). In general, carnivores translocated for conflict management have shown strong homing abilities, poor survival and reproduction, and a tendency to resume depredations (Linnell et al. 1997). However, translocation remains popular among wildlife managers and the general public as a non-lethal technique and will likely continue to be used as a management tool (Craven et al. 1998), especially for species that are rare or endangered (Linnell et al. 1997).

Wolves are protected under the Endangered Species Act in the northwestern United States and are now recovering in areas of Montana, Idaho, and Wyoming (Bangs et al. 1998) where they were previously extirpated largely because they threatened livestock (Young & Goldman 1944). Livestock production is a large part of the economy in this region and wolves invoke considerable controversy when they kill livestock (Bangs et al. 1998, 2004). Finding effective methods to mitigate livestock damage has been important in attempts to improve local tolerance while working toward wolf recovery.

Wolves are managed by the United States Fish and Wildlife Service (USFWS) in Montana, Idaho, and Wyoming within three separate areas: northwest Montana, central

Idaho, and the Greater Yellowstone Area (GYA) (USFWS 1987, Figure 1). As part of wolf recovery plans (USFWS 1987), wolves were encouraged to naturally recover northwest Montana via dispersal from Canada (Ream et al. 1991) and were reintroduced to central Idaho and the GYA in 1995 and 1996 (Bangs & Fritts 1996, Fritts et al. 1997). At the onset of wolf recovery efforts, core areas were identified within each recovery area that provided protected habitat such as national parks and wilderness areas (USFWS 1987, Figure 1). Each core contained minimal livestock and abundant wild game (USFWS 1987). In central Idaho and the GYA, core areas proved to provide good habitat, as many wolf packs settled within these areas. However, most wolves in northwest Montana settled in habitat outside protected areas and therefore closer to humans and livestock (USFWS 1999).

The wolf population grew rapidly after reintroduction. By the end of 2002, wolves reached recovery levels (USFWS 2003) by establishing ≥ 30 breeding pairs (an adult male and female with ≥ 2 pups survive through the end of the year) across the 3 recovery areas for 3 consecutive years (E. E. Bangs, USFWS, personal communication). During this period of wolf recovery, the USFWS attempted to manage livestock depredations in a way that minimized impacts to wolf packs (USFWS 1999).

Translocation was the primary non-lethal method used by the USFWS to mitigate livestock damage in the early phases of wolf recovery (Bangs et al. 1995, 1998). Translocation is now less practical because rapid growth and expansion of the wolf population has resulted in fewer available release sites. The goal of translocation was to reduce livestock depredations at original conflict sites and to release wolves into areas where they would be most likely to survive and not come into conflict with livestock.

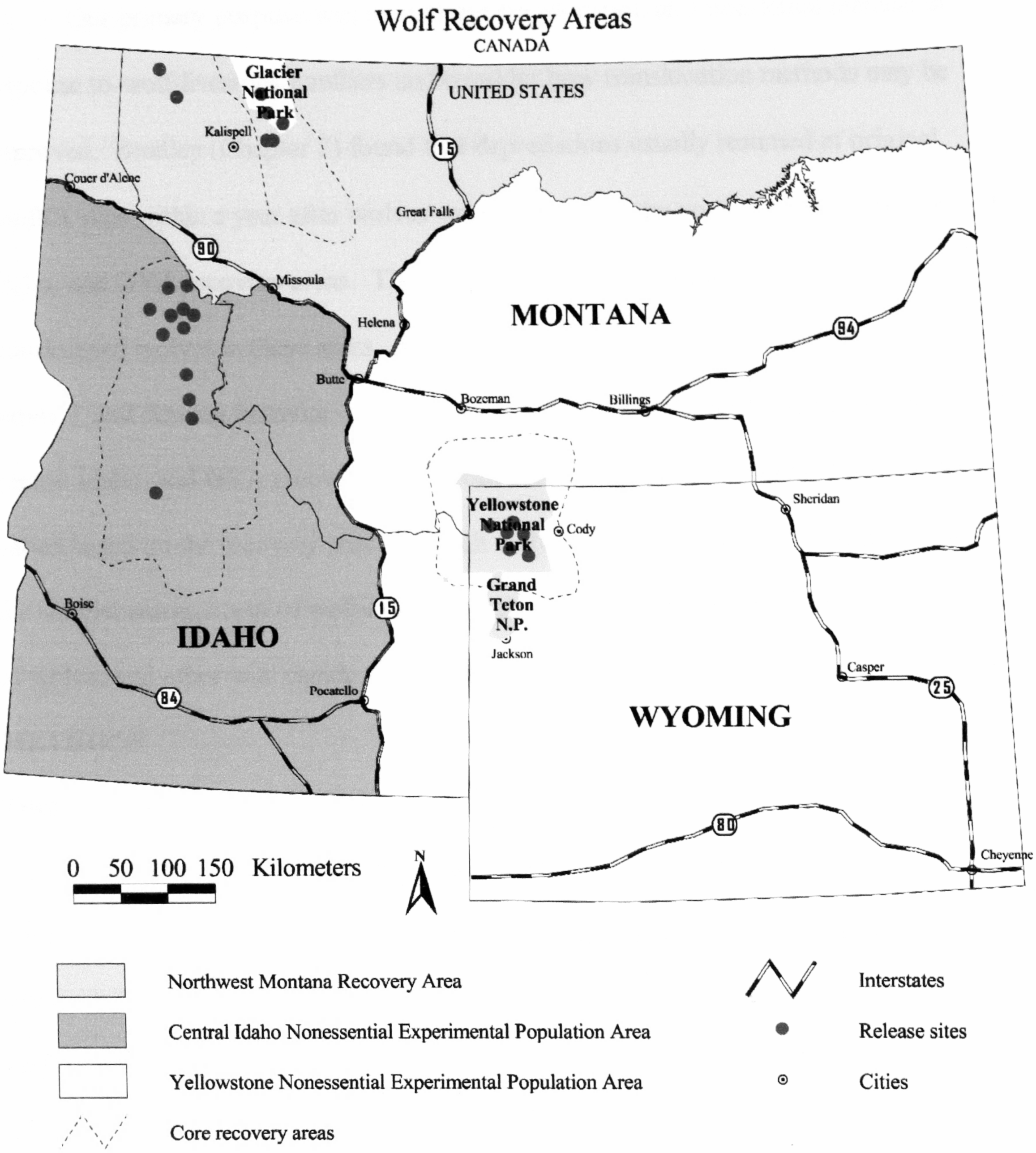

Figure 1. Sites where translocated wolves were released in Montana, Idaho, and Wyoming, 1989-2001. Some release sites were used multiple times.

Our primary purpose was to evaluate translocation as a non-lethal method in response to wolf-livestock conflicts and consider how translocation methods may be improved. Bradley (Chapter 2) found that depredations usually resumed at original conflict sites within a year after wolves were removed in the northwest Montana, central Idaho, and GYA recovery areas. Therefore, we sought to examine the fate of translocated wolves in these areas. We evaluated depredations, pack establishment, survival, and homing behavior of all translocated wolves in the northwest Montana, central Idaho, and GYA recovery areas from 1989-2002. We considered how results varied based on the recovery areas in which wolves were released. Our results are useful for conflict management of wolves in our region and may prove useful for management of wolves and other wild canids elsewhere.

METHODS

Translocation and Monitoring

We compiled data from 1989-2002 on all wolves translocated in response to conflicts with livestock. In most cases, wolves were translocated after confirmed livestock depredations had occurred but sometimes were moved preemptively when conflict appeared imminent. Translocation events involved both individuals and groups of wolves. Some individuals were relocated multiple times.

Wolves were darted from a helicopter or foot-hold trapped, radio-collared, transported, and then either hard (immediately) or soft (temporarily held in enclosure) released. We define hard releases as those where wolves were released $\leq$ 7 days of capture. All soft released wolves were held $\geq$ 28 days. Two types of soft release methods were used: 1) standard soft release, and 2) modified soft release. Wolves given a standard soft release were released directly from their holding facility whereas wolves given a modified soft release were transported away from their holding facility before release. Modified soft releases were used with wolves in northwest Montana and standard soft releases were used with wolves in Yellowstone. Most wolves in central Idaho were hard released.

Release sites were selected in areas with abundant wild ungulates, without livestock, and with no other known wolf packs present. All release sites in Idaho and the GYA were located within core recovery areas (the central Idaho wilderness and Yellowstone National Park). Release sites in northwest Montana were located both inside (Glacier National Park and the Flathead National Forest) and outside core recovery areas (Figure 1).

The USFWS monitored radio-collared wolves in Montana and Wyoming outside Yellowstone National Park, the National Park Service monitored wolves in Yellowstone, and the Nez Perce Tribe monitored wolves in Idaho. Monitoring was conducted by fixed-wing aircraft and on the ground. Wolves were located 2-4 times per month but efforts increased when livestock conflicts occurred and when research data were being collected. Poor weather conditions and shortage of funding decreased frequency of monitoring at times.

Data Analysis

DEPREDATIONS AND PACK ESTABLISHMENT

We determined whether translocated wolves ever depredated livestock and established or joined a wolf pack after release. Wildlife Services (WS) personnel confirmed wolf depredation on livestock using standard protocols (Roy & Dorrance

1976, Paul & Gipson 1994). Wolves were considered to have depredated if they were located in close proximity to confirmed depredation sites or were known members of depredating packs. Because wolves are territorial, we assumed that packs were responsible for those depredations that were confirmed within their territory. We define a wolf pack as ≥ 2 wolves consistently located within a defended territory. Wolves that homed back to original packs were considered established only if they survived and did not depredate for ≥ 1 year post-release.

SURVIVAL

We estimated and compared annual survival rates of translocated wolves from 1989-2002 with all other radio-collared wolves in Montana, Idaho, and Wyoming from 1982-2002. Annual survival rates were calculated according to Trent & Rongstad (1974) by $[1 - (\text{no. of mortalities/radio-days})^{365}]$. We calculated 95% confidence intervals using the Poisson approximation to the binomial (Krebs 1999). Radio-days of translocated wolves were counted beginning the day of release and ending the first day mortality was detected, the last day of location (if missing), or on 31 December 2002 if the animal was still alive.

We report cause-specific mortality of translocated wolves. USFWS law enforcement investigated all wolf deaths. Carcasses were necropsied either by the Montana Department of Fish, Wildlife and Parks Wildlife Investigations Laboratory in Bozeman, Montana, or by the USFWS National Fish and Wildlife Forensics Laboratory in Ashland, Oregon to determine cause of death.

The Cox proportional hazards model was used to examine variables possibly associated with survival of translocated wolves (Cox & Oakes 1984, White & Garrott 1990). This semiparametric model relates survival times of individuals that either died or are censored (alive or missing) to explanatory covariates using the hazard rate (instantaneous mortality rate). An assumption of this model is that the individual hazard functions for each variable are proportional to each other over time (proportional hazards assumption). We examined the proportional relative risk (RR) of each variable in the model. The RR is the exponentiated coefficient for each variable in the model and estimates the change in hazard associated with a one unit change in the variable of interest. When RR is > 1, the variable is positively associated with increasing risk, and thus, decreasing survival.

We considered the following covariates for inclusion in the model: recovery area (northwest Montana, central Idaho, GYA), age class (pup, yearling, adult), sex, release method (hard, soft), and furthest distance moved after release. We only included those covariates in the model that met the proportional hazards assumption. Continuous variables must be converted into categories to test this assumption; therefore, we split the distance variable into 3 groups: 1) = 1- 49 km, 2) = 50 – 134 km, 3) = 135 – 363 km. For each variable, we plotted –ln[-ln(survival)] against time to examine proportionality. For variables that did not meet this assumption, we tested for differences in survival using the log-rank test (White and Garrott 1990, Krebs 1999). Release method was correlated with recovery area in central Idaho and the GYA, therefore we ran a separate model for translocated wolves in northwest Montana and included release method as the only covariate.

HOMING BEHAVIOR

Successful homing of wolves back to capture sites was generally an undesirable outcome of translocation, because of the potential to resume depredations upon return. We therefore sought to determine what factors were associated with homing behavior.

We used contingency tables and chi-square tests to compare wolves that homed back to capture sites and those that did not home in relation to the following categorical variables: recovery area (northwest Montana, GYA, or central Idaho), release method (hard or soft), sex, and ageclass (adult = > 2 years old, sub-adult = < 2 years old). We compared translocation distances (km) between wolves that homed and those that did not home using the Mann-Whitney *U* test. We also used the Mann-Whitney *U* test to examine whether the furthest distance that wolves traveled after release differed between hard and soft released wolves, and between standard soft released and modified soft released wolves.

We used circular statistics (Batschelet 1981, Zar 1999), following methods used by Fritts et al. (1984) and Fritts et al. (2001), to determine if individuals that did not successfully home showed any tendency to move directionally toward capture sites after release. We recorded the ultimate direction for each translocated wolf (azimuths from release sites to end points). End points included mortality sites, last known locations (if animal was missing or alive but without a defined territory), the site of next capture (if translocated again), or the center of home ranges (if animal was alive with a defined territory). We standardized end point azimuths for all wolves in relation to a common homing direction (0°) then we tested for uniform distribution of end point azimuths using the Rayleigh test (White and Garrott 1990, Zar 1999). The Rayleigh test uses a measure of angular dispersion (r), scaled from 0 (high dispersion) to 1 (low dispersion), to determine whether azimuths are concentrated. We then used a V test (Batschelet 1981, Zar 1999) to determine whether end point azimuths were directionally oriented toward the homing direction (0°). Because we standardized around a single homing direction, reported azimuths do not reflect compass directions.

We also examined and report cases where translocated wolves showed release site fidelity and therefore did not exhibit any homing behavior. We define cases of release site fidelity as those where wolves established a territory that encompassed the original release site. Sample size was too small to permit statistical analysis.

SAMPLING

Sometimes individuals that were translocated together remained cohesive after release and therefore were tied in their subsequent fates. Wolves that remained cohesive were therefore not independent from each other in regards to their behavior. For all analyses, we treated groups of cohesive wolves as 1 individual when their fates were tied, except when measuring survival rates. For analyzing factors related to homing behavior, sex and ageclass differed within cohesive groups. Therefore, for this analysis, we excluded those cohesive groups where sexes varied and assigned the ageclass of adult to those groups that included an adult (all cases) because adults are dominant and known to lead pack behavior (Mech 1970, Packard 2003).

Some individual wolves were relocated multiple times. These wolves were sampled differently for each analysis. We considered whether translocated wolves ever depredated and established a pack, regardless of the number of times individuals were relocated. For survival modeling, we only considered factors as they were for an individual's final translocation event. Wolves that were relocated multiple times may have homed back to conflict sites under different circumstances. Therefore, we examined homing behavior for each translocation.

RESULTS

Eighty-eight wolves were translocated, 12 of which were moved multiple times (7 wolves were moved twice and 5 wolves were moved three times). By including these multiple relocations of the same individual, wolves were translocated in 42 events involving 105 wolves (range = 1-10 individuals per event, $\bar{x}$ = 2.5, Table 1, Appendix I). Thirteen individuals were moved preemptively and the rest reactively in response to livestock conflicts. Wolves were relocated 74 – 515 km from capture sites.

Table 1. Number of translocated wolves and translocation events in response to conflicts with livestock in the northwest Montana (NWMT), Greater Yellowstone (GYA), and central Idaho (CI) recovery areas, 1989-2001.[a] Wolves were not present in the GYA and CI recovery areas from 1989-94.

	NWMT		GYA		CI		Total	
Year	Wolves	Events	Wolves	Events	Wolves	Events	Wolves	Events
1989-94	9	3	-	-	-	-	9	3
1995	2	1	0	0	0	0	2	1
1996	0	0	8	4	2	2	10	6
1997	3	1	22	7	3	2	28	10
1998	0	0	6	1	4	3	10	4
1999	10	2	0	0	6	5	16	7
2000	0	0	2	1	10	5	12	6
2001	13	2	0	0	5	3	18	5
Total	37	9	38	13	30	20	105	42

[a] Includes a total of 88 individuals, some of which were moved multiple times. No wolves were translocated in 2002.

Depredation and Pack Establishment

We examined 63 individuals and 9 cohesive groups of translocated wolves to determine whether they depredated or established/joined a pack after release. Nineteen wolves (27%) depredated after release (Table 2). Thirteen of these wolves that depredated (18%) created new conflicts; the remainder returned home and resumed depredating in their original territory. Wolves that were preemptively moved appeared no less likely to avoid conflicts; 3 of 7 (43%) of these individuals or groups that were preemptively relocated depredated after release.

Table 2. Number of wolves translocated due to conflicts with livestock that depredated livestock and/or established territories[a] after release in the northwest Montana (NWMT), Greater Yellowstone (GYA), and central Idaho (CI) recovery areas, 1989-2002.

	NWMT	GYA	CI	Total (%)
Depredated				
Established	2	5	3	10 (14%)
Not Established	3	5	1	9 (13%)
Did Not Depredate				
Established	4	2	8	14 (19%)
Not Established[b]	26	4	9	39 (54%)

[a] Either joined or established a pack of ≥ 2 wolves with a defended territory
[b] Includes13 missing wolves (5 in NWMT, 1 in GYA, 7 in CI).

Most translocated wolves (67%) were never known to establish or join a pack (Table 2). This estimate includes 13 wolves that disappeared (5 in northwest Montana, 1 in the GYA, and 7 in central Idaho) and 26 that died before pack establishment was documented. Of those wolves that established, 8 new packs were formed (3 in northwest Montana, 3 in the GYA, and 2 in central Idaho) and 4 pre-existing packs were supplemented. All of these packs produced pups and contributed to wolf recovery goals for ≥ 1 year.

Survival

We examined annual survival for 88 translocated wolves (mortalities = 58, radio-days = 42,160) and 399 radio-collared, non-translocated wolves (mortalities = 214, radio-days = 248,513) and found survival was lower for translocated (0.60, 95% CI: 0.53 – 0.68) than non-translocated wolves (0.73, 95% CI: 0.70 – 0.76). Annual survival of translocated wolves differed by recovery area; survival was lowest in northwest Montana (0.41, 95% CI: 0.28 – 0.57) compared to central Idaho (0.71, 95% CI: 0.57 – 0.82) and the GYA (0.65, 95% CI: 0.54 – 0.78). Overall, most mortality of translocated wolves was human-caused, with government control and illegal killing composing the first and second leading cause of mortality, respectively (Table 3).

Table 3. Number of wolves translocated due to conflicts with livestock that died from human, natural, and unknown causes in the northwest Montana (NWMT), Greater Yellowstone (GYA), and central Idaho (CI) recovery areas, 1989-2002.

Cause	NWMT	GYA	CI	Total
Human				
Control	4 (15%)	7 (39%)	4 (29%)	15 (26%)
Illegal	10 (38%)	1 (6%)	3 (21%)	14 (24%)
Legal[a]	5 (19%)	2 (11%)	0 (0%)	7 (12%)
Vehicle	1 (4%)	2 (11%)	0 (0%)	3 (5%)
Other[b]	2 (8%)	1 (5.5%)	0 (0%)	3 (5%)
Natural				
Starvation	3 (12%)	0 (0%)	0 (0%)	3 (5%)
Hunting injury	0 (0%)	1 (5.5%)	1 (7%)	2 (4%)
Other[c]	0 (0%)	4 (22%)	0 (0%)	4 (7%)
Unknown	1 (4%)	0 (0%)	6[d] (43%)	7 (12%)

[a] Legal mortalities include 5 wolves harvested in Canada (NWMT) and 2 wolves caught in the act of attacking livestock shot by ranchers as permitted under section 10(j) of the ESA (GYA).
[b] Other human mortalities include 1 wolf that died from a snare wound, 1 wolf euthanized for a foot injury (NWMT), and 1 wolf that pulled an M44 (GYA).
[c] Other natural mortalities include 1 wolf killed by other wolves, and 3 unknown causes.
[d] Two of these unknown mortalities were thought to be illegal kills but could not be proven.

Of 83 individuals included in the Cox proportional hazards model, 57 (69%) died and 31% were censored due to collar failure (n = 2), disappearance (n = 13), or because they were still alive at the end of 2002 (n = 11). We only included recovery area and release method in the model because the variables sex, age class, and furthest distance moved did not meet the proportional hazards assumption. Recovery area was the only significant variable in the model. Risk was over two times higher for translocated wolves in northwest Montana (RR = 2.27, 95% CI: 1.1 – 4.7, P = 0.025) than in central Idaho. Release method was correlated in central Idaho and the GYA. Therefore, we examined possible effects of this variable on survival for translocated wolves in northwest Montana only. Risk was higher for hard released than soft released wolves in northwest Montana (RR = 2.7, 95% CI: 1.215 – 5.984, P = 0.015). We tested for differences in survival for factors that we did not include in the model using the log-rank test and found no difference between sexes ($\chi^2_1 = 0.18$, P = 0.67), age classes ($\chi^2_2 = 1.17$, P = 0.56), or furthest distance moved after release ($\chi^2_2 = 1.19$, P = 0.55).

Homing Behavior

Sixteen (20%) of 81 individuals or cohesive groups (12 individuals, 3 pairs, and 1 group of 6 wolves) successfully homed back to capture sites. More adults (36%) than sub-adults (11%) homed back to capture sites ($\chi^2_1 = 6.88$, P = 0.009). No pups were found to home on their own. More hard released (30%) than soft released (8%) wolves homed ($\chi^2_1 = 5.83$, P = 0.016). Hard released wolves generally traveled further distances after release than soft released wolves (Z = -2.16, P = 0.03). We found no difference between standard and modified soft released wolves in regards to the furthest distance wolves traveled after release (Z = -0.46, P = 0.65). Fewer wolves homed in northwest

Montana (6%) compared to the GYA (33%) and central Idaho (28%, $\chi^2_2 = 7.87$, $P = 0.02$). Wolves that were translocated shorter distances were more likely to home ($Z = -2.6$, $P = 0.009$). Wolves traveled distances of 74 – 316 km (Median = 147.5 km) to return home. Sex was the only variable not related to homing ($\chi^2_1 = 0.019$, $P = 0.89$).

We examined 67 individuals that did not successfully home to determine whether their ultimate direction showed directionality toward their capture site. Mean angle of directional movement was 41.7° (angular deviation = 70.4°) in relation to the 0° standardized homing direction. Ultimate directions were not uniformly distributed around a circle ($r = 0.245$, $z = 4.02$, $P = 0.017$) and showed directionality toward home ($V = 12.26$, $u = 2.12$, $P < 0.025$).

Most wolves, whether attempting to home or not, moved away from the release site. Only 4 translocations resulted in release site fidelity. All 4 of these translocations involved groups of wolves that were relocated together and 3 of these 4 translocations involved almost complete family groups. These were the only 3 cases, out of all the translocations we examined, where family groups were relocated together. In one case, a male and female that were hard released at the same site in separate groups found each other and pair bonded. Two other cases involved situations where family groups were soft released together and remained cohesive. These packs composed 3 of the 8 new packs that were established as a result of translocations.

DISCUSSION

Depredation and Pack Establishment

Wolf translocation was not always effective at reducing depredations. Although most translocated wolves did not depredate after release, depredations still often persisted at the original conflict site from which wolves were translocated (Chapter 2). Those translocated wolves that depredated in a new area, therefore, created additional conflicts. This incurred additional expense, evidenced by the fact that government control was the largest source of mortality of translocated wolves.

We found a higher level of subsequent depredation (27%) by translocated wolves than in Minnesota (13%, Fritts et al. 1985). This is not surprising because depredation rates in Minnesota were based on recapture of translocated wolves during subsequent control actions (Fritts et al. 1985). All translocated wolves in our study were radio-collared and periodically monitored, which helped improve our estimate. However, depredations are not always reported or found (Bangs et al. 1998, Oakleaf et al. 2003); therefore, depredation rates are inherently under-estimated.

Most translocated wolves (67%) died or disappeared without ever establishing a territory. Some missing wolves may have disappeared due to collar failure or may have traveled outside the area being monitored. Therefore, survival and pack establishment by these wolves may have been undetected. For the most part, however, these wolves were considered lost from the population.

Translocated wolves helped further wolf recovery by establishing 8 new packs and supplementing an additional 4 packs, all of which contributed toward wolf recovery goals. This contribution is most notable in northwest Montana, where the wolf population has grown more slowly than in central Idaho or the GYA (USFWS 2003). These results concur with data in Minnesota that showed that wolves translocated for depredation management were capable of becoming functioning members of the wolf population again (Fritts et al. 1985, Fritts 1992).

Survival

We were not surprised to find lower survival for translocated wolves compared to non-translocated wolves. Translocated wolves could simply be at higher risk because of being released into an unfamiliar environment. However, wolves translocated in Minnesota (also protected by the ESA) for depredation management had similar survival rates as resident wolves (Fritts et al. 1985). Our survival estimate may be more precise because we had a larger sample size of radio-collared wolves, or regional differences could have affected survival. However, mortality is predominantly human-caused for both translocated and non-translocated wolves in the northwestern U.S. (Bangs et al. 1998) and Minnesota (Fritts and Mech 1981, Fritts et al. 1985).

Release site selection is considered one of the most important factors affecting translocation success for a variety of species (Griffith et al. 1989, Wolf et al. 1996, Linnell et al. 1997). Although we did not look specifically at characteristics of release sites, we found that recovery area was the most important factor related to survival of translocated wolves. Translocated wolves in central Idaho had the highest rate of survival (0.71) and pack establishment (52%) than the other 2 recovery areas. Concordantly, Idaho has the largest area of available and suitable wolf habitat (Oakleaf 2002). Translocated wolves in northwest Montana had lower survival (0.41) and pack establishment (17%) than those in central Idaho. Interestingly, core habitat in northwest Montana, as identified by the Wolf Recovery Plan (USFWS 1987), seems to have proven mostly inadequate because most colonizing wolves have settled outside this area (USFWS 1999) and therefore in closer contact with humans. Illegal killing was a larger source of mortality for translocated wolves in northwest Montana than in central Idaho and the GYA, perhaps as a result of closer human contact (Table 3). Also, wolves may wander more easily from northwest Montana into Canada where wolves are unprotected and legally hunted (Pletscher et al. 1997).

Soft releasing appeared to help improve survival of translocated wolves in northwest Montana, but we found that soft releases were correlated with release location. Many of the first translocated wolves in northwest Montana were hard released in Glacier National Park. These early translocations proved largely unsuccessful (Bangs et al. 1995, 1998, USFWS 1999) and several wolves starved (likely as a result of prey scarcity within the area of release). Thereafter, release methods were changed. Later translocations occurred at different release sites and often involved soft releases. Therefore we cannot make definitive conclusions about the relationship between soft release and survival of translocated wolves.

Homing Behavior

Translocated wolves showed a strong homing tendency in our region, which often brought them back into conflict with livestock. Homing behavior is well documented for wolves and other large carnivores. At least 8 of 104 wolves (8%) translocated for depredation management in Minnesota were known to successfully home (Fritts et al. 1984), as did 1 of 4 adult wolves released from captivity in Alaska (Henshaw and Stephenson 1974). Individuals reintroduced in Michigan, central Idaho, and Yellowstone all showed directional inclinations toward home (Weise et al. 1975, Fritts et al. 2001). Other large carnivores such as cougars (Ruth et al. 1998) and black (Rogers 1986) and brown bears (Blanchard and Knight 1995) have also demonstrated homing ability.

Similar to a study of translocated wolves in Minnesota (Fritts et al. 1984), we found that adult wolves were more likely to home, pups did not home, and wolves that homed were translocated shorter distances than other wolves. However, we found that wolves traveled further distances (≤ 316 km) to return home in our region than those in Minnesota (≤ 64 km, Fritts et al. 1984) and Alaska (282 km, Henshaw and Stephenson 1974). Dispersing wolves, on the other hand, have been known to travel as far as 886 km (Mech and Boitani 2003).

We found that soft released wolves were less likely to return to capture sites than hard released wolves. Soft released wolves also traveled shorter distances after release than hard released wolves. Similarly, wolves that were soft released as part of reintroduction efforts in Yellowstone National Park showed less directional movement toward home and traveled shorter distances than wolves that were hard released in central Idaho (Fritts et al. 2001). Therefore, we concur with Fritts et al. (2001) that shorter post-release movements and reduced homing behavior are likely a result of the soft release method.

However, two types of soft release methods were used in our study. Wolves that were transported away from their holding facility before release (modified soft release) could reasonably be expected to travel more widely after release than those that had an opportunity to acclimate to their release site by being released directly from their pen (standard soft release). Interestingly, we found no difference for standard and modified soft released wolves in the furthest distance wolves traveled after release. However, because all modified soft releases occurred in northwest Montana, ability of wolves to travel further distances may have been confounded by other factors affecting the low survival seen in this area. Therefore, more information is needed to fully evaluate differences between the two soft release methods.

Wolves showed strong homing behavior; therefore, overall translocation success may have been affected by habitat quality between capture and release sites. All but one translocation in northwest Montana had large areas of human habitation and livestock production between the original capture site and the release site. Homing urges may therefore have brought wolves into closer contact with humans and may have partly accounted for the lower success of translocations in northwest Montana. In Idaho, where translocation success was highest, most translocated wolves were relocated from the southern outskirts of the central Idaho wilderness north into the wilderness area. Consequently, habitat between capture and release points was predominantly wilderness and there was less potential for contact with humans and livestock if wolves traveled toward home.

Ideally, managers hoped that translocated wolves would stay at release sites and establish packs. We found that this only occurred for 4 translocations, resulting in 3 new packs. However, all of these translocations involved groups of wolves and these included the only 3 cases where family groups were relocated together. Almost all family groups that were soft released in Yellowstone National Park as part of reintroduction efforts, stayed together and established a territory, some of which stayed near release sites (Fritts et al. 2001). Therefore, releasing family groups together may also be a good strategy for encouraging release site fidelity for wolves that are translocated for depredation management purposes, given that the release site provides adequate habitat.

MANAGEMENT RECOMMENDATIONS

Translocating wolves away from conflict sites had both benefits and drawbacks in comparison to lethal removal. Benefits of translocations included the establishment of new packs and the augmentation of existing packs, which both served to help further wolf recovery. In addition, the public generally considers translocation of predators a more desirable management option than lethal removal by the government (Montag et al. 2003). On the other hand, translocated wolves sometimes caused additional conflicts with livestock that incurred extra expense and often resulted in their eventual lethal removal. Translocation was most useful in our region during early phases of wolf recovery, when encouraging establishment of new packs was of high priority.

Now that wolf populations are higher, non-lethal efforts may be better focused on prevention and mitigation of depredations at the original site of conflict. Such efforts may prove useful, not only to reduce conflicts, but to help build a foundation for promoting co-existence within communities in the long-term. Non-lethal preventative methods are being developed for application in a variety of situations (Bangs and Shivik 2001, Musiani et al. 2003, Shivik et al. 2003).

Translocation may still be an important tool for populations where the survival of individual animals is critical and other non-lethal management tools are unavailable or impractical. In such cases, we suggest special consideration be given to release sites and release methods. We found that translocation success depended most on the area in which wolves were released. We concur with other researchers who emphasized the importance of release site selection (Griffith et al. 1989, Wolf et al. 1996, Linnell et al.

1997) and suggest that the extent of available habitat should be given the highest consideration when translocating wide-ranging animals such as wolves. More specifically, we suggest that translocations involving animals that exhibit homing tendencies may be more successful if habitat quality between the capture and release sites is suitable. Homing tendencies may otherwise bring animals into close contact with humans, which could result in higher mortality and further conflicts with livestock.

Adequate release sites and available habitat are often limited. In these cases, efforts should especially be focused on using release methods with the greatest chance of limiting post-release movements and homing behavior. Though initially more costly, soft releasing and translocating family groups may be useful strategies that may help reduce homing behavior and increase release site fidelity.

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Chapter 4. Assessing Factors Related to Wolf Depredation of Cattle in Fenced Pastures in Montana and Idaho

Abstract: Managing wolf (*Canis lupus*) depredation on livestock is expensive and controversial, therefore managers seek to improve and develop new methods to mitigate conflicts. Determining which factors put ranches at higher risk to wolf depredation may provide ideas for ways to reduce livestock and wolf losses. We sampled cattle pastures in Montana and Idaho that experienced confirmed wolf depredations ($n = 34$) from 1994-2002 and compared landscape and selected animal husbandry factors with cattle pastures on nearby ranches where depredations did not occur ($n = 62$). Pastures where depredations occurred were more likely to have elk (*Cervus elaphus*) present, were larger in size, had more cattle, and grazed cattle further from residences than pastures without depredations. Using classification tree analysis, we found that a higher percentage of vegetation cover was also associated with depredated pastures in combination with the variables above. We found no relationship between depredations and carcass disposal methods, calving locations, calving times, breed of cattle, or the distance cattle were grazed from the forest edge. Most pastures where depredations occurred during the wolf denning season (April 15 – June 15) were located closer to wolf dens than nearby cattle pastures without depredations. Physical vulnerability, especially of calves, may also increase risk of depredation.

INTRODUCTION

Recovery of wolves to the northwestern United States has brought about much controversy and concern regarding impacts to livestock producers (Fritts et al. 2003, Bangs et al. 2004). Historically, wolves were persecuted largely due to conflicts with livestock (Young and Goldman 1944) but now, under protection from the Endangered Species Act, have made a comeback via dispersal from Canada into northwest Montana (Ream et al. 1991) and reintroduction into Yellowstone National Park and the central Idaho wilderness in 1995 and 1996 (Bangs and Fritts 1996, Fritts et al. 1997). The rapid growth, and recent downlisting of the wolf population to threatened status [United States Fish and Wildlife Service (USFWS) 2003] has initiated efforts to facilitate transition from federal to state management. Wolf depredation on livestock remains a central issue of contention within this process.

Finding effective strategies to reduce wolf depredation on livestock is beneficial for both livestock producers and wolves. Ranchers are compensated by Defenders of Wildlife for confirmed losses to wolves (Fischer 1989), but not all depredations are found or leave enough evidence to confirm cause of death (Bangs et al. 1998, Oakleaf et al. 2003). Depredating wolves are often killed by the USFWS when other options are unavailable or impractical. Lethal control is expensive and unpopular with wolf supporters but is believed necessary to offset dissention in ranching communities (Mech 1995, Bangs et al. 2004). Although lethal control may provide short-term relief, better long-term solutions are needed if wolves and humans are to co-exist in some areas (Chapter 2).

A number of different non-lethal management tools are being tested and developed by the USFWS and non-governmental organizations (Bangs and Shivik 2001, Shivik et al. 2003). Translocation of depredating wolves has been discontinued (Chapter 3); therefore current non-lethal research has largely focused on implementation of on-site wolf deterrents (Musiani et al. 2003, Shivik et al. 2003). Depredations appear to affect some livestock producers more than others (Mech et al. 2000, Chapter 2). Therefore, effective implementation of such methods would benefit from a better understanding of why depredations occur where they do.

Depredations involve primarily cattle and sheep in Montana, Idaho, and Wyoming (Bangs et al. 2004). Though a greater overall number of sheep have been killed (Bangs et al. 2004), more conflicts involve cattle (Chapter 2). Depredations occur both in fenced pastures and on open range and as such, require different approaches to non-lethal management. Livestock are usually monitored less when grazed on open range, making depredations more difficult to detect (Oakleaf et al. 2003) or prevent, whereas depredations are likely detected more frequently when cattle are held in confined pastures. We focused our research on cattle depredations that occurred within confined pastures to provide information we thought would most facilitate development of non-lethal preventative methods.

Researchers in Canada and Minnesota have suggested that ranches may be more vulnerable to wolf depredation when they have greater vegetation cover (Fritts 1982, Bjorge 1983, Fritts et al. 1992) and when cattle are grazed closer to the forest edge (Gunson 1983, Tompa 1983, Bjorge and Gunson 1985). Remote calving locations, presence of livestock carrion (Fritts 1982, Tompa 1983, Fritts et al. 1992), low relative abundance of natural prey, and greater number of livestock (Gunson 1983) were also suggested as predisposing factors.

Treves et al. (2004) and Mech et al. (2000) compared variables between depredated and non-depredated sites. Treves et al. (2004) examined landscape level variables in areas with and without depredations in Minnesota and Wisconsin at 2 scales (townships and farms) to build a predictive model of where depredations were likely to occur. They found that townships with depredations had a higher proportion of pasture and higher densities of deer, and lower proportions of crop lands, coniferous forest, herbaceous wetlands, and open water; farms with depredations were larger, had lower road density, and fewer crop lands (Treves et al. 2004). Mech et al. (2000) compared characteristics and management practices of cattle farms in Minnesota with and without chronic depredations and found that depredated farms were larger in size, had more cattle, and grazed cattle further from human dwellings. Effects of carcass disposal methods remained equivocal.

Researchers have not examined how cattle management and pasture characteristics might work together to increase depredation risk. Some variables could also be dependent on the time (year or season) in which they occurred. Such factors as proximity of pastures to wolf dens and potential physical vulnerability of depredated animals have not been previously examined. Conditions are different in the western U.S. than in the Midwest in that there is greater topography, seasonality in ungulate movements, and larger ranches (Fritts et al. 1992). Therefore, different factors may be important in explaining depredation sites. We sought to further elucidate factors potentially related to cattle depredations by measuring factors as they were at the time of the depredation event and then examining which factors best described pastures that experienced depredations.

METHODS

To determine what factors may be related to wolf depredation of cattle in fenced pastures, we compared pastures at ranches that experienced confirmed depredations to pastures at nearby ranches that had not experienced depredations. United States Department of Agriculture Wildlife Services personnel are contracted by the USFWS to investigate and confirm wolf depredations using standard protocols (Roy and Dorrance 1976, Paul and Gipson 1994). In some cases, evidence for confirmation may be lacking (Bangs et al. 1998, Oakleaf et al. 2003) or livestock producers may choose not to report losses to the government. Because of these concerns, we questioned each rancher we interviewed regarding any unconfirmed wolf depredations they may have experienced.

Areas were sampled within each of the 3 wolf recovery management areas in the northwestern United States designated by the USFWS (USFWS 1987): northwest Montana, central Idaho, and the Greater Yellowstone recovery areas. We selected communities within these areas that had experienced multiple conflicts between 1994-2002. These included: Grave Creek, Pleasant Valley (and surrounding area), the East Front, and Deerlodge areas in northwest Montana; the Bitterroot Valley, Stanley Basin, Clayton, Salmon, and Bighole Valley areas in the central Idaho recovery area; and Paradise Valley in the Greater Yellowstone area (Figure 1).

Cattle ranches in our study area often had multiple pastures where cattle were grazed and cattle were often moved to different pastures during different times of the year. Thus, conditions changed depending on the pasture in which cattle were confined. For this reason, we treated the pasture as the sampling unit and recorded variables as they were at the time the depredation occurred. Adjacent pastures that were grazed simultaneously on the same ranch were treated as one pasture. Some ranchers experienced multiple depredations by the same or different wolf packs, and in different seasons or years when conditions had changed and cattle were in different pastures. We sampled pastures as they were during each depredation scenario as long as: 1) the pasture (sampling unit) had changed, or 2) different wolf packs were involved in the depredation events.

Ranchers were contacted and in-person interviews were conducted to gather data on characteristics of pastures. For each ranch where a depredation occurred, we sought out up to 5 nearby ranches that had not experienced depredations and collected data on applicable pastures that were grazed at the time of the depredation event. We selected ranches that also ran cattle, did not have any claimed wolf depredations, and were located within the depredating wolf pack's known home range (based on radio-telemetry). We included ranches that claimed to have had wolves on their property that were within reasonable traveling distance for a wolf in cases where radio-telemetry data were unavailable. In such cases, we cross-referenced by contacting local wildlife officials regarding pack activity.

Ranchers at both depredated and non-depredated ranches were questioned regarding the following factors as they were at the time of the depredation: 1) location of grazed pastures, 2) total number of cattle grazed, 3) breed of cattle grazed (Angus, Hereford, Angus/Hereford cross, Charolais, or a mix of these and other breeds), 4) type of cattle grazed (cow/calf pairs, yearlings, or mix), and 5) whether elk were present or absent, in and around pastures. In addition, we asked ranchers how they generally disposed of livestock carcasses (removed or not). We considered carcasses that were

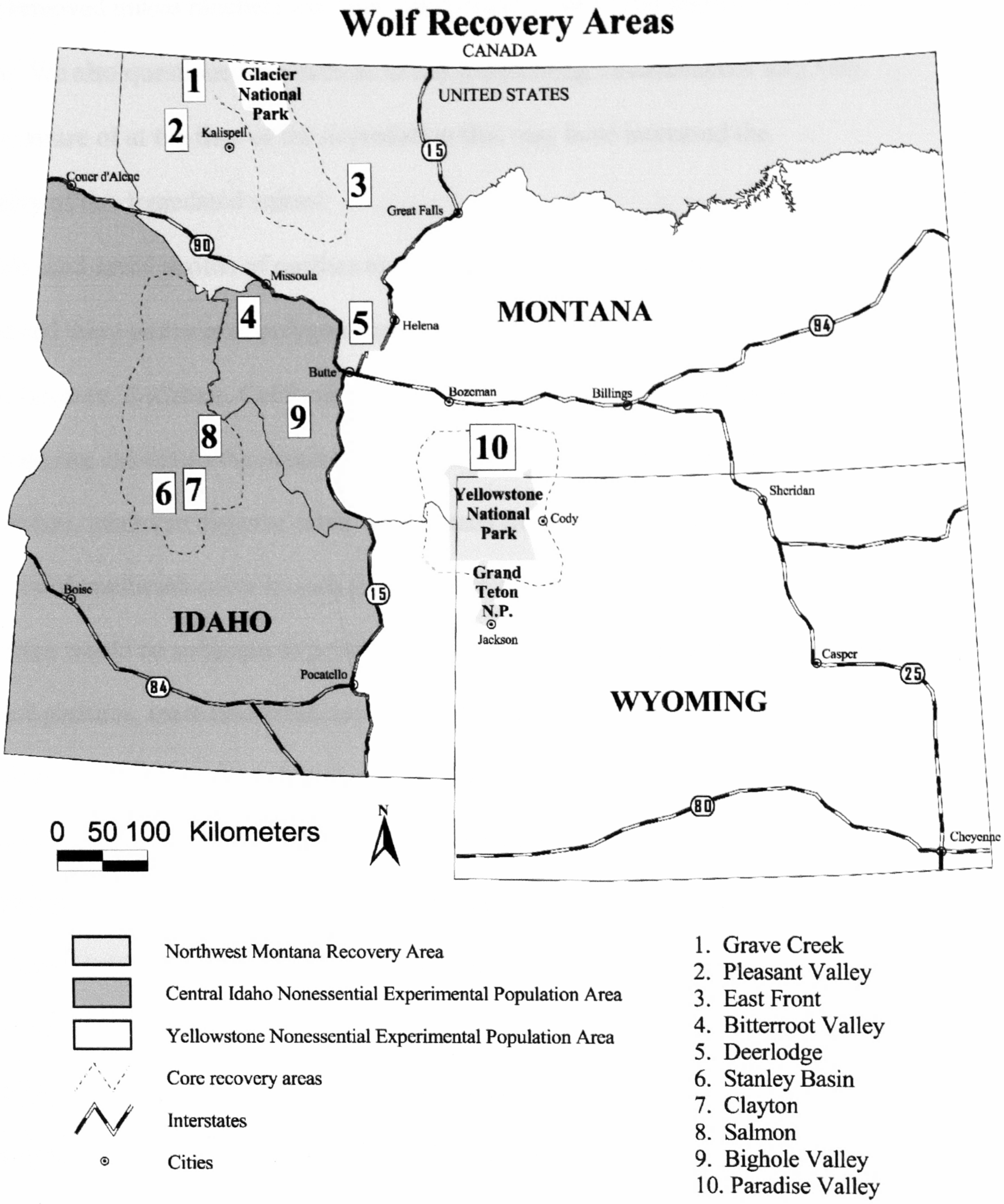

Figure 1. Cattle ranching communities where interviews were conducted regarding factors related to wolf depredations in the northwest Montana, central Idaho, and Greater Yellowstone wolf recovery areas, 1994-2002.

buried as removed unless ranchers indicated that predators had been known to excavate carcasses. We also questioned ranchers as to any extenuating circumstances they may have been aware of at the time of the depredation that may have increased the vulnerability of the depredated animal.

We used aerial photos of ranches to draw pasture boundaries during interviews then digitized these pastures as polygons using ArcView (Environmental Systems Research Institute, Redlands, California, USA). Using these digitized pasture and aerial photo layers, we calculated the maximum distance cattle were grazed from human residences (m), minimum distance cattle were grazed from contiguous forest edge (m), and percent of tree/brush cover in each pasture. We assumed that vegetation visible on aerial photos would be sufficient to provide cover for a wolf. We predicted that ranches with larger pastures, more tree/brush cover, greater numbers of cattle, cattle grazed further away from residences, and with cattle grazed closer to the forest edge would be more vulnerable to wolves. We also predicted that presence of elk and livestock carcasses could draw wolves into cattle pastures, increasing the risk for depredations.

Some variables we measured were applicable only to those ranches that experienced depredations during certain seasons. For those ranches that experienced calf depredations during the calving season, and for associated non-depredated ranches, we asked questions pertaining to: 1) calving locations (out in pastures or in corrals/sheds), 2) date calving began, and 3) duration of calving (days). We predicted that those ranches that calved out in pastures rather than in corrals or sheds, started calving earlier, and calved for a longer period of time would be more vulnerable to wolf depredation. Locations of wolf dens were mapped and distances (km) between dens and pastures were calculated for those depredations that occurred during the denning season (April 15 – June 15). We predicted that pastures experiencing depredations were closer to dens than pastures without depredations.

To determine which individual variables were related to pastures experiencing depredations, we conducted univariate tests. For continuous variables, we used the Mann-Whitney *U* test to compare pastures with and without depredations. For categorical variables, we used contingency tables and chi-square tests.

We used classification tree analysis (Breiman et al. 1984, Venables and Ripley 1997) to provide descriptive information on what combination of variables best classified pastures as depredated and non-depredated. A classification tree is a non-parametric method used to classify observations using a decision tree-like framework. Both categorical and continuous variables can be used to construct a dichotomous key, or tree, for classification. The splits, or branches of the tree are determined by searching for splits that minimize overall model error. Thus, the variables and associated split levels are selected that best classify pastures as depredated or not. We set a minimum of 15 observations to be used to create a new split in the tree, where each division at a split must contain a minimum of 5 observations. This is somewhat larger and thus, more conservative than thresholds of 10 and 5, respectively, suggested as default values by Venables and Ripley (1997). Such thresholds serve as a means to decrease the complexity of the tree and the potential for overfitting the data.

RESULTS

We sampled 31 ranches with 34 pastures where depredations occurred and 51 ranches with 62 pastures where no depredations occurred. Although interviews were conducted with 58 ranchers without confirmed depredations, 7 (12%) ranchers claimed unconfirmed losses to wolves and were excluded from the analysis. Of the 31 ranches we sampled that had experienced confirmed depredations, 15 (48%) claimed to have had additional unconfirmed depredations. Response rate was high (99%); only 1 rancher that experienced a depredation refused to be interviewed.

Sampling was distributed fairly evenly between the 3 recovery areas. We sampled 13, 13, and 8 pastures that experienced depredations, and 18, 22, and 22 pastures without depredations in the northwest Montana, central Idaho, and the Greater Yellowstone recovery areas, respectively. We found nearby ranches that had not experienced depredations for all but 4 depredated ranches. Three ranches were located together in northwest Montana and the only 2 cattle ranches located nearby both claimed unconfirmed wolf losses. Another ranch was located in central Idaho and although other cattle were grazed nearby, none were held in fenced pastures.

Pastures that experienced depredations were larger ($Z = -2.3$, $P = 0.02$), had more cattle ($Z = -2.1$, $P = 0.03$), and had cattle grazed further from human residences ($Z = -2.3$, $P = 0.02$) than pastures without depredations (Table 1). These 3 ranch size-related factors were correlated ($r = 0.4 – 0.64$, $P < 0.01$). We also found that pastures with depredations were more likely to have elk present ($\chi^2_1 = 9.03$, $P = 0.003$) than pastures without depredations. There was insufficient evidence to conclude that pastures with and without depredations were different in regards to distance from the forest edge ($Z =$ -

0.58, $P = 0.56$) (Table 1), percent vegetation cover ($Z = -1.5$, $P = 0.13$) (Table 1), cattle breed ($\chi^2_4 = 5.78$, $P = 0.22$), cattle type ($\chi^2_2 = 4.4$, $P = 0.11$), and carcass disposal ($\chi^2_1 = 0.46$, $P = 0.5$).

Table 1. Mean values (± 95% confidence limits) of characteristics of 34 pastures that experienced depredations (depredated) and 62 pastures[a] that did not experience depredations (non-depredated) in Montana and Idaho, 1994-2002.

	Depredated	Non-Depredated
Pasture size (ha)	201 ± 66	124 ± 35
Number of cattle	585 ± 207	358 ± 99
Furthest distance cattle grazed from residences (m)	1849 ± 383	1314 ± 183
Closest distance from pasture to forest edge (m)	1071 ± 519	1582 ± 537
Percent vegetation cover	15 ± 7	10 ±4
Date calving begins (julian date)[a]	46 ± 11	43 ± 9
Duration of calving (days)[a]	74 ± 7	73 ± 8

[a] Sample size for calving practices (date calving begins and duration of calving) = 14 depredated and 23 non-depredated pastures.

Ranchers reported extenuating circumstances for 7 of the 34 (21%) depredation scenarios that we measured. All 7 depredations involved calves: 3 were killed during snowstorms (1 of these calves was already weak), 3 had been separated from mother cows (1 calf was also sick), and 1 had been grafted onto a mother cow that had already lost its calf to predation earlier that spring. Based on these anecdotal reports, we suggest physical vulnerability as an additional factor likely related to wolf depredation.

To determine whether calving practices were related to depredations, we more closely examined 14 ranches where calves were depredated during the calving season and 23 ranches that ran cow/calf pairs that did not experience depredations. We found no differences between ranches for calving locations ($\chi^2_1 = 0.32$, $P = 0.58$), calving duration ($Z = -0.46$, $P = 0.65$), and the date that calving began ($Z = -0.46$, $P = 0.65$) (Table 1).

However, 5 of these 14 (36%) ranches were involved in the 7 extenuating circumstances as described above. Thus, individual vulnerability of calves may play a bigger role than calving practices in increasing the risk of depredation.

Nine pastures experienced depredations during the wolf denning season. Information on den site locations was available for all but 2 of these cases. We found that 5 of 7 pastures where depredations occurred during the wolf denning season were located closer to wolf dens than nearby grazed pastures on ranches without depredations (Table 2).

Table 2. Distance (km) between pastures and wolf dens for cattle ranches that experienced depredations during the wolf denning season (April 15 – June 15) and nearby cattle ranches that did not have depredations (Non-Dep)[a], in the northwest Montana, central Idaho, and Greater Yellowstone wolf recovery areas, 1994 – 2002.

	Depredated	Non-Dep	Non-Dep	Non-Dep
Northwest Montana				
Den #1	3.8	1.7	4.3	4.3
Central Idaho				
Den #2	4.4	9.9	17.8	18.9
Den #3	0.9	2.9	6.7	-
Den #4	2.3	3.0	-	-
Greater Yellowstone				
Den #5	3.6	4.2	4.2	5.2
Den #6	6.6	6.9	7.6	8.8
Den #7	12.7	5.2	12.5	14.5

[a] 2 ranches that had depredations during the denning season were not included because den location information was unavailable.

Using classification tree analysis, pastures were correctly classified as depredated or not depredated in 80 (83%) of 96 cases. Pastures predicted to experience depredations ($n = 18$) were those that had elk present, > 310 head of cattle, and that were far (> 1,487.5 m) from human residences (Figure 2). If there was < 310 head of cattle, then pastures with depredations were predicted to have yearlings ($n = 5$), or otherwise were predicted to have vegetation cover > 20.5% (Figure 2). Pastures that did not have elk present were predicted to experience depredations if vegetation cover was > 13.5% and size of the pasture was > 56 ha (Figure 2). If these conditions were not satisfied, then pastures were predicted not to experience depredations.

DISCUSSION

Elk presence was the single variable most related to pastures with depredations and was also the best predictive variable in classification tree analysis of pastures with depredations in combination with other variables. Elk are an important prey species for wolves in northwest Montana (Boyd et al. 1994, Kunkel et al. 1999), central Idaho (Husseman 2002), and the Greater Yellowstone area (Mech et al. 2001, Smith et al. 2004). Wolves are likely attracted to areas with large numbers of elk. Elk and other wild ungulates often overlap areas of cattle production in the winter and early spring to seek forage within and around cattle pastures.

Similar to Mech et al. (2000) and Treves et al. (2004), we found that factors related to ranch size appeared to differentiate ranches that experienced depredations from those that had not. We found that pastures that were larger, had more cattle, and had cattle grazed further from residences were more likely to have depredations. We also found that these 3 variables were correlated, as did Mech et al. (2000). Larger herds of

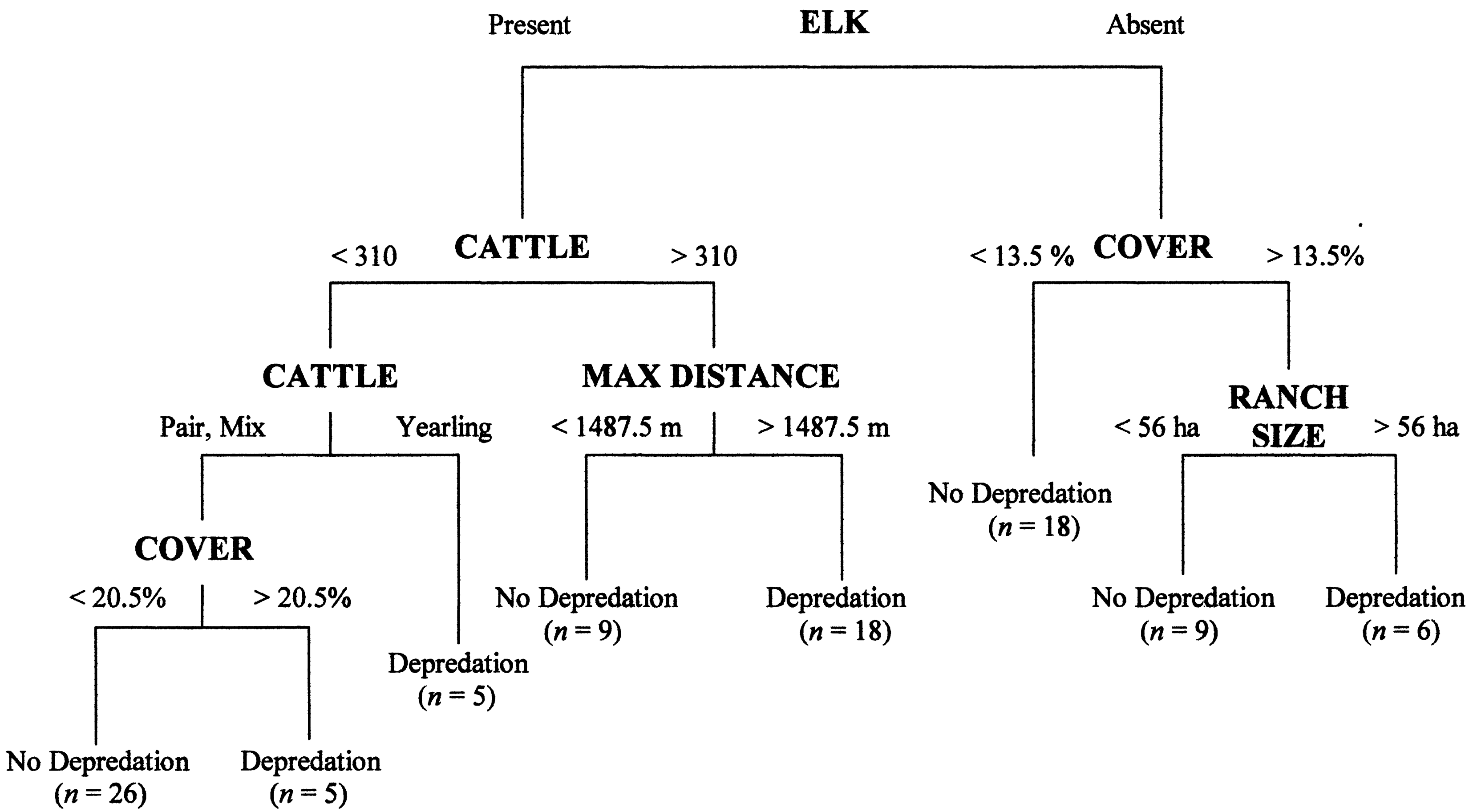

Figure 2. Classification tree relating characteristics of cattle pastures to whether they experienced depredations by wolves or not, in Montana and Idaho, 1994-2002.

cattle could serve as a greater attractant to wolves, or increase the probability that some individuals within the herd may be more physically vulnerable than others. Larger pastures could increase the risk of contact with wolves. Mech et al. (2000) was skeptical that grazing cattle further from residences was a causative factor because depredations were known to occur near houses in Minnesota. We found that depredations also sometimes occurred near houses for those ranches that we sampled and therefore, the distance cattle were grazed from residences may not have been a causative factor in our study, either.

We found no evidence that improper carcass disposal was related to depredation problems. However, we were only able to ascertain how ranchers generally disposed of carcasses. Some ranches (especially small operations) did not always have carcasses to dispose. We believe the question of proper carcass disposal could be better addressed by having information as to carcass presence or absence near the time of the depredation, and more specifically, whether wolves had fed on carcasses. Such fine scale information was impossible to reconstruct and therefore would need to be collected at the time the depredation occurred.

Farmers with chronic depredations in Minnesota surprisingly reported proper carcass disposal more than farmers without depredations (Mech et al. 2000). These equivocal results, along with a disparity between sources, raised the question of whether false reporting had occurred (Mech et al. 2000). Unlike Minnesota, proper carcass disposal is not a legal issue in Montana and Idaho. However, the USFWS would not implement lethal control of depredating wolves if livestock carcasses were not removed (USFWS 1999). Therefore, false reporting on carcass disposal methods remains a possibility, because we had no adequate means of cross-validating responses. We found no other reasons, however, to suspect that ranchers had incentives to report false information on other variables we measured.

Using classification tree analysis, we found that a higher percent of vegetation cover and presence of yearling cattle also classified pastures with depredations. Cover has been shown to increase livestock depredation risk by other carnivores as well (Nass et al. 1984, Quigley and Crenshaw 1992). Yearlings have been suggested as potentially more vulnerable to predation than adult cattle because of inherent curiosity and skittishness. However, most ranchers shipped calves off in the fall and did not keep yearlings, therefore our sample is too small to adequately address this question.

Values from which continuous variables were split within the classification tree should be interpreted carefully because they are descriptive of our data set as a whole and may not be accurate for other situations. While classification tree analysis provided a useful descriptive tool for our data, inference is limited to pastures that we sampled. We concentrated our effort on areas that had experienced multiple conflicts and thus non-randomly subsampled from a population of ranches that is inherently incomplete because as mentioned earlier, not all depredations may be detected, reported, or confirmed.

Occurrence of unconfirmed wolf depredations could have affected our data by reducing the probability that we would have found differences between pastures with and without depredations. We therefore questioned ranchers as to whether they claimed any unconfirmed losses to wolves. Based on these responses, we cannot determine for certain whether these losses were actually caused by wolves. However, we believed that ranchers would be more likely to suspect wolf depredation as a cause of mortality when other losses had occurred nearby. By excluding those ranchers that suspected wolf depredations, we believe we reduced the risk of such error. That ranchers with confirmed depredations claimed more unconfirmed depredations than ranchers with no confirmed depredations is interesting. This could reflect higher vulnerability of such ranches, effects of learned behavior of wolves, or a higher tendency to suspect wolves because of previous problems.

Wild ungulates preyed upon by wolves tend to be disproportionately young or old or in poor physical condition (Boyd et al. 1994, Mech et al. 1995, Kunkel et al. 1999, Mech and Peterson 2003). Therefore it would be reasonable to expect that such factors could also increase the vulnerability of cattle to depredation. Not surprisingly, calves are killed more often than adult cattle in Montana, Idaho, and Wyoming (Bangs et al. 2004), Minnesota (Fritts 1982, Fritts et al. 1992), and Canada (Dorrance 1982, Bjorge 1983, Gunson 1983). Oakleaf et al. (2003) found that wolves on public grazing allotments in Idaho selected the smallest calves. Reports we received from ranchers suggested that some depredated calves were physically vulnerable. Such situations may sometimes have been undetected, therefore could be biased low in our sample. Still, ranchers are likely more aware of such conditions when cattle are in fenced pastures than when grazed on open range. Wolves, however, are still capable of killing healthy adult wild ungulates and cattle.

Oakleaf et al. (2003) found on a grazing allotment in central Idaho, that the livestock permittee whose cattle had the highest level of spatial overlap with a wolf pack home range, also had the most depredations. Similarly, we found that those pastures that were larger, and thus likely had more cattle exposed to wolves, incurred more depredations. Although we sampled pastures located within wolf home ranges, it is possible that pastures with depredations fell within areas of higher wolf use. This is also supported by our findings that pastures with depredations were more likely to have elk present and be located closer to wolf dens. Thus, pastures that experience depredations may simply be best characterized as those that are located within good wolf habitat where cattle are more exposed to wolves.

MANAGEMENT RECOMMENDATIONS

Calves tend to be most vulnerable to wolf predation, thus efforts may be best focused on their protection. Those individuals that show known physical weakness or other vulnerability might be best temporarily kept in barns or sheds, if possible, especially when wolves are in the vicinity. Hay supplies could be better protected (with electric fences or other means) that may otherwise serve to draw elk, and thus wolves, into pastures during early spring when cattle are calving. Hazing elk out of calving pastures could also be helpful. Such methods may be time consuming and unaffordable for most livestock producers, thus successful implementation will likely require outside resources.

Improved monitoring and management of wolf denning activity may also prove useful. Wolf dens that are located close to ranches can be filled in subsequent years to encourage denning elsewhere. Such a tactic was successfully implemented in Paradise Valley, Montana in 2001 to keep a wolf pack from denning close to livestock again. In this case, wolves moved to an alternative den site in Yellowstone National Park. Cattle could also be moved away from wolf dens if other pasture is available.

We believe that depredation problems still represent unique situations that require consideration on a case-by-case basis to determine the best course of action. Even by focusing our research on cattle depredations in fenced pastures, we found depredations to be complex events that may result from a number of factors. Ranches should be individually assessed to determine which methods are most applicable given the time of year and sites where depredations occurred. Larger cattle operations may be more likely to have persistent conflicts; therefore finding non-lethal ways of reducing depredations on these ranches may provide a better long-term cost-effective strategy than lethal control (Chapter 2).

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Appendix I. Wolves translocated in response to conflicts with livestock in the northwest Montana, Greater Yellowstone, and central Idaho wolf recovery areas, 1989-2001.

Table 4.1 Wolves translocated in response to conflicts with livestock in the northwest Montana wolf recovery area, 1989-2001.

Wolf Pack	Wolf #s	Year	Release Method	Capture Site	Release Site
Marion	2, 53, 64, 71	1989	Hard	Marion, Montana	Glacier National Park
Ninemile	109, 1211, 1513	1991	Hard	Ninemile Valley, Montana	Glacier National Park
Sawtooth	4445, 4647	1994	Hard	Augusta, Montana	Glacier National Park
Boulder	19, 20	1995	Soft (Modified)	Boulder, Montana	Glacier National Park
Browns Mdw	58, 79, 2425	1997	Hard	Browns Meadow, Montana	Spotted Bear
Pleasant Valley	115, 117, 119, 128	1999	Hard	Pleasant Valley, Montana	Spotted Bear
Bass Creek	45, 46, 48, 49, 50, 57	1999	Soft (Modified)	Bass Creek, Montana	Spotted Bear
Boulder	276, 278, 280, 284, 286	2001	Soft (Modified)	Boulder, Montana	Lake Koocanusa, Montana
Gravelly	204, 206, 229, 230, 231, 232, 233, 234	2001	Soft (Modified)	Gravelly Mtns, Montana	Yaak

Table 4.2. Wolves translocated in response to conflicts with livestock in the Greater Yellowstone Area wolf recovery area, 1989-2001.[a]

Wolf Pack	Wolf #s	Year	Release Method	Capture Site	Release Site
Disperser	3	1996	Soft (Standard)	Paradise Valley, Montana	Yellowstone National Park
Soda Butte	13, 14, 24, 43, 44	1996	Soft (Standard)	Fishtail, Montana	Yellowstone National Park
Soda Butte	15	1996	Soft (Standard)	Fishtail, Montana	Yellowstone National Park
Dispersers	29, 37	1996	Soft (Standard)	Paradise Valley, Montana	Yellowstone National Park
Disperser	47	1996	Soft (Standard)	Fishtail, Montana	Yellowstone National Park
Sawtooth	63, 64, 65, 66, 67, 68, 69, 70, 71, 72	1996	Soft (Standard)	Augusta, Montana	Yellowstone National Park
Disperser	27	1997	Soft (Standard)	Fishtail, Montana	Yellowstone National Park
Disperser	48	1997	Hard	Fishtail, Montana	Yellowstone National Park
Disperser	68	1997	Hard	Pinedale, Wyoming	Yellowstone National Park
Disperser	63	1997	Hard	Fishtail, Montana	Yellowstone National Park
Nez Perce	29, 37, 67, 70, 72, 92	1997	Hard	Dillon, Montana	Yellowstone National Park
Nez Perce	29, 37, 67, 70, 72, 92	1997	Soft (Standard)	Dillon, Montana	Yellowstone National Park
Chief Joseph	34, 198	2000	Hard	Paradise Valley, Montana	Yellowstone National Park

[a] Some individuals were relocated multiple times.

Table 4.3. Wolves translocated in response to conflicts with livestock in the central Idaho wolf recovery area, 1989-2001.[a]

Wolf Pack	Wolf #s	Year	Release Method	Capture Site	Release Site
Disperser	B20	1996	Hard	McCall, Idaho	Clearwater National Forest
Bighole	B11	1996	Hard	Bighole Valley, Montana	Selway-Bitterroot Wilderness
Bighole	B7	1997	Soft (Standard)	Bighole Valley, Montana	Selway-Bitterroot Wilderness
Bighole	B7, B11	1997	Soft (Modified)	Bighole Valley, Montana	Clearwater National Forest
Boulder	B43	1998	Soft (Standard)	Deerlodge, Montana	Selway-Bitterroot Wilderness
Moyer Basin	B51	1998	Hard	Moyer Creek, Idaho	Selway-Bitterroot Wilderness
Jureano	B52, B54	1998	Hard	Salmon, Idaho	Selway-Bitterroot Wilderness
Disperser	B40	1999	Hard	Salmon, Idaho	Payette National Forest
Disperser	132	1999	Hard	May, Idaho	Selway-Bitterroot Wilderness
Whitecloud	B64, B65	1999	Hard	Clayton, Idaho	Clearwater National Forest
Stanley Basin	B68	1999	Hard	Stanley Basin, Idaho	Selway-Bitterroot Wilderness
Disperser	B45	1999	Hard	John Day, Oregon	Clearwater National Forest
Twin Peaks	B18, B35	2000	Hard	Clayton, Idaho	Selway-Bitterroot Wilderness
Whitecloud	B36, B63, B85, B86	2000	Hard	Clayton, Idaho	Clearwater National Forest
Jureano	B80, B81	2000	Hard	Carmen, Idaho	Selway-Bitterroot Wilderness
Stanley Basin	B98	2000	Hard	Stanley Basin, Idaho	Clearwater National Forest
Stanley Basin	B27	2000	Hard	Stanley Basin, Idaho	Clearwater National Forest
Wildhorse	B103	2001	Hard	Copper Basin, Idaho	Clearwater National Forest
Dispersers	B63, B100	2001	Hard	Bighole Valley, Montana	Selway-Bitterroot Wilderness
Dispersers	B80, B114	2001	Hard	Bighole Valley, Montana	Selway-Bitterroot Wilderness

[a] Some individuals were relocated multiple times.