EFFECTS OF WOLVES ON LIVESTOCK CALF SURVIVAL AND MOVEMENTS IN CENTRAL IDAHO

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Abstract: We examined interactions between wolves (*Canis lupus*) and domestic calves (*Bos tauras*) within a grazing allotment in central Idaho, USA, to evaluate the role of wolves on calf survival and movements. During the 1999 and 2000 grazing seasons, we radiomarked 231 calves/year—representing 33% of the calf population—on the Diamond Moose Association (DMA) grazing allotment and monitored their survival and movements relative to wolf distribution. Overall, calf survival was high (≥95%), with relatively few mortalities ($n = 13$) among the marked population. Of the 13 calf mortalities, 8 were unrelated to predation (pneumonia, unknown natural causes, fire), 4 were wolf predation, and 1 was coyote predation. Calves selected by wolves were younger than the surviving cohort by an average of 24 days (wolf-killed: 31 Mar ± 13 days [mean birthdate ± SE], $n = 4$; live population: 7 Mar ± 1.6 days, $n = 207$; $P < 0.05$). Calf movement patterns and group size did not vary relative to the level of spatial overlap with wolves. However, vulnerability to predation appeared to be correlated with spatial proximity of calves to wolf home ranges and rendezvous sites. These results suggest that in our study area, the overall impact of wolves was not significant on either calf survival or behavior.

Gray wolves were extirpated from much of western North America due in part to conflicts with domestic livestock (Young and Goldman 1944, Mech 1970). Accordingly, wolf–livestock conflicts were viewed as an important concern of the Northern Rocky Mountain Wolf Recovery Plan (U.S. Fish and Wildlife Service 1987). Wolves dispersed naturally into Montana (Ream et al. 1989) and later were reintroduced into Yellowstone National Park and central Idaho (Fritts et al. 1997). The present recovery plan relies on the nonessential experimental designation of wolves in the Greater Yellowstone Area (GYA) and central Idaho to allow for management flexibility designed to mitigate wolf–livestock conflict (U.S. Fish and Wildlife Service 1994). Currently, wolf populations in Wyoming, Montana, and Idaho have caused less livestock damage than initially anticipated (U.S. Fish and Wildlife Service 1987). However, in each of these states, some livestock producers who experienced confirmed wolf depredations also reported an increased level of missing calves, which may be attributed to wolf predation (Bangs et al. 1998); areas in Minnesota

had similar reports (Fritts 1982). Even with increased monitoring, some wolf kills inevitably remain undetected due to rapid and extensive consumption by wolves and scavengers, rapid carcass decomposition during summer, and the rugged, inaccessible, forested terrain where such kills often occur (Bangs et al. 1998). Thus, a clear need exists to better understand the direct impact of recolonizing wolves on livestock mortality.

Few data are available on either the factors predisposing livestock to predation, or the effect of wolf predation risk on livestock behavior. Some studies have suggested that wolves select disproportionately for domestic livestock calves (Fritts 1982, Bjorge and Gunson 1985, Fritts et al. 1992). Other studies indicate that livestock depredation and winter severity may be negatively correlated due to the availability of alternate prey (Mech et al. 1988). In wild ungulates, factors such as age (Mech 1970, Peterson 1977, Nelson and Mech 1981, Ozoga and Verme 1986) and juvenile and maternal nutritional status (Peterson 1977; Mech et al. 1987, 1991; Kunkel and Mech 1994) have been identified as factors predisposing ungulate prey to wolf predation. Similar patterns may characterize wolf selection of domestic livestock prey. Furthermore, colonizing wolves may have subtle impacts on wild ungulates, such as decreased weight gain among juveniles due to increased vigilance and altered movements patterns related to predation risk (Berger et al. 2001). Similarly, wild

ungulate movement patterns and group sizes may affect wolf prey selection (Nelson and Mech 1991, Carbyn et al. 1993, Kunkel and Mech 1994, Carbyn 1997). Cattle could portray similar patterns, if wolf predation risk is intense enough to influence their behavior.

Our study examined 3 objectives: (1) the causes of death among calves found in areas recolonized by wolves in Idaho; (2) the attributes of wolf-killed calves and factors related to their vulnerability to predation; and (3) the movement and group size responses of calves to wolf predation risk. We predicted that wolves would select calves that were younger and closer to wolf territories, and that predation risk would cause an increase in both herd sizes and movement distances.

STUDY AREA

Our study was conducted on the Diamond Moose grazing allotment (DMA) in Lemhi County, northwest of Salmon, Idaho (45°11′N, 113°54′W, Fig. 1). The landscape is mountainous with dense coniferous cover, interspersed with small grassy meadows and riparian areas. The allotment contains portions of 5 drainages flowing into the Salmon River, with 5 livestock permittees grazing approximately 688 cow/calf pairs annually within the 30,000 ha allotment (Fig. 1).

The Jureano wolf pack established in 1996, with pup production occurring in 1997 (6 pups), 1998 (4), 1999 (9), and 2000 (6). Control actions and subsequent relocations in 1998 reduced pack size to an estimated 6 wolves prior to the 1999 breeding season. Natural mortalities (7 pups), control actions (2 adults killed, 2 pups relocated), illegal mortality (1 adult), and dispersal (2 adults) resulted in the disappearance of all individuals from the Jureano wolf pack by late winter 2000. However, 1 of the dispersing adults returned with an unknown adult to form a new pack in the area by spring 2000. This pack produced pups in the same den and used the area in a similar fashion as the 1999 pack (Fig. 1). Thus, during our study, livestock on the DMA were exposed to 4–15 wolves (2–6 adults, 2–9 pups) during 1999 and 8 wolves (2 adults, 6 pups) during 2000, occupying the same general area.

Reported cattle losses (deaths and unexplained missing) on U.S. Forest Service public grazing allotments within the pack's territory increased during 1996–1998 relative to historic trends (U.S. Forest Service, unpublished data). Missing calves comprised most of the increase in reported losses; loss rates for cows and bulls did not increase
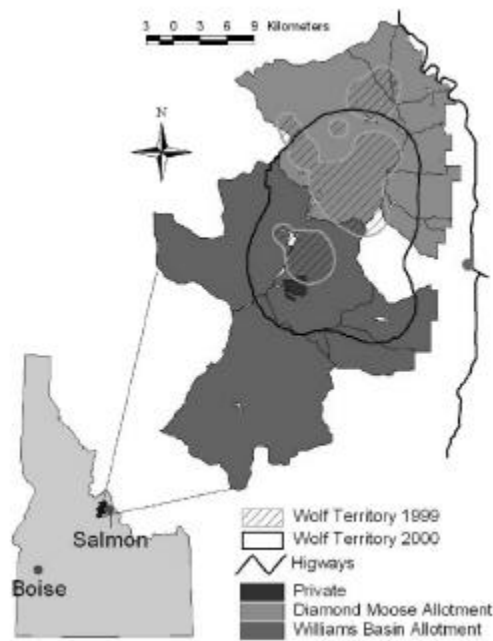

Fig. 1. Wolf–cattle study area in central Idaho, USA. Intensive study was conducted on the Diamond Moose Allotment (DMA) in the portions where wolf home ranges overlapped.

during the same period. Wolves, mountain lions (*Felis concolor*), bobcat (*Lynx rufus*), black bear (*Ursus americanus*), and coyote (*Canis latrans*) were possible predators on livestock in the area.

METHODS

Survival

During the 1999 and 2000 grazing seasons (May–Oct), ear-tag radiotransmitters (Advanced Telemetry Systems, Isanti, Minnesota, USA) equipped with 2-hr mortality switches were attached to 462 calves (231/yr). This sample represented approximately one-third of all calves grazed on the allotment. Gender, birthdate, mother's age, ear-tag number, and livestock permittee were recorded for each marked calf. Calves were monitored daily via ground radiotelemetry to determine spatial distribution and survival. Calves found to have a transmitter in mortality mode were promptly located and covered in the field to prevent scavenging. Personnel from USDA/APHIS, Wildlife Services (WS) examined dead calves within 1 day of initial discovery to determine cause of death (Roy and Dorrance 1976, Fritts 1982). A veterinarian performed necropsy on carcasses to determine cause of death

for nonpredation mortalities. To calculate cause-specific mortality rates, we categorized all causes of deaths as predation (wolves, coyotes, mountain lion, black bears, or other) or nonpredation (pneumonia, unknown natural causes, or fire).

We analyzed calf survival via Poisson regression (Selvin 1995). We used a stepwise model building approach that evaluates the relationship between multiple independent variables and a rate, which in our case consisted of the daily mortality rate (Selvin 1995, Wirsing et al. 2002, Murray in press). We used calf gender, birthdate, mother's age (in years), year and month of study, wolf activity period (high or low, dummy coded for the time period when wolf–cattle interaction occurred on the DMA), and livestock permittee as independent variables and made available for retention in the model. Livestock permittee was included in this analysis to block for differential predation pressure and management practices among permittees. We used forward stepwise regression (Hosmer and Lemeshow 2000:116–128) to develop our survival models, with the partial likelihood ratio test determining variable retention (level to enter, $P = 0.05$). We used wolf-caused mortalities as dependent variables in the survival analyses to fully evaluate the attributes of wolf-killed calves relative to the surviving members of the cohort. This was accomplished by right-censoring mortalities that were not of interest in the particular analysis. Finally, we checked the robustness of each model via backward selection. The influence of continuous variables on mortality rate was described using rate ratios (rate ratio $= e^{\text{coefficient}}$), which enables assessment of the relative risk provided by a given variable. Cause-specific calf mortality rates were calculated by $\{1-[1-(\text{deaths/radio days})^{\text{days}}]\}$, where deaths represented specific causes of death (Trent and Rongstad 1974).

Space Use

A random sample of marked calves (20–30) was located on a weekly basis to evaluate their positions relative to weekly aerial locations of radiomarked wolf pack members (1–4 individuals located/week). We estimated calf locations via aerial telemetry and ground locations using a Trimble Global Positioning System unit. For each calf location, we recorded cover type (forest, mountain brush, riparian, grass, other), position on slope (bottom, lower slope, mid-slope, upper slope, ridge top, bench), percent slope (0–20, 21–40, >40%), aspect (N, E, S, W), and group size

associated with the calf (1–10, 11–20, 21–30, >40) based on visual observation. Home ranges (95% fixed kernel [FK]) and core use areas (50% FK) with least squares cross validation (LSCV; Worton 1995) were constructed to describe spatial distribution of cattle belonging to each permittee, using the animal movement extension in the program ARCVIEW (Hooge et al. 1999, Environmental Systems Research Institute 2000).

Nez Perce tribal biologists located wolves from the ground with an H antenna 2–3 times per week and assigned locations to 1-km^2 grids overlaid on 1:24,000 topographic maps. Four wolves were radiomarked during 1999 (alpha pair, and 2 subadults), while only the alpha female was radiomarked during 2000. We constructed points using a Geographical Information System (GIS) based on the center of the grids containing quality wolf locations (e.g., biologist refined the location to less than 4 km^2). Combined with weekly aerial locations, this information was used to construct home ranges using the same methods as described above for cattle. All home ranges were constructed with >30 independent locations (Seaman et al. 1999). We compared the amount of home-range overlap between individual permittee's cattle and wolves, with wolf kill rate, to assess whether degree of overlap predisposed calves to wolf predation.

Wolf home ranges for each year were transformed onto a fixed-kernel grid, such that each area within the home range could be assigned a specific wolf utilization level (Hooge et al. 1999, Roloff et al. 2001). Cattle locations were then overlaid to determine the level of wolf predation risk at each calf location. We compared calf locations at various wolf predation risk levels to determine whether calf movement patterns or cattle group size varied with proximity to core wolf use areas.

We used a general linear model (Proc GLM; SPSS Inc. 2000) to analyze calf movement, with daily movement distance as the dependent variable. As independent variables, we used year; days between locations (with distances added as a block to remove the possible decreased resolution between temporally disparate locations); wolf use level (continuous variable, 1–100% FK) at the initial location of the calf; wolf use level at the final location of the calf; and the amount of wolf use change between calf locations. We analyzed cattle gregarious behavior relative to proximity to wolves using log-linear models (Proc Catmod: SAS Institute 1996), with estimated group size as the dependent variable. As independent variables,

Table 1. Parameter estimates for a livestock calf survival model of the Diamond Moose Association in central Idaho, USA (1999–2000), with wolf predations as the dependent variable.

Parameter	Coefficient	95% CI	ΔAIC	P
Significant parameters				
Intercept	−9.269[a]			
Permittee	24.479[a]	—[b]	5.9	0.005
Wolf activity	24.146[a]	—[b]	4.6	0.010
Birthdate (days)	0.046[a]	±0.041	3.0	0.025
Nonsignificant parameters				
Year			−1.0	0.322
Month			−1.0	0.321
Sex (proportion male)			−1.5	0.481
Mother's age (yr)			0.2	0.178

[a] Coefficient values are for the time of entry into the model rather than the final model.
[b] Confidence intervals were not included for dummy coded variables.

we used habitat, position on slope, and wolf use level (categorical variable; no wolf use, 99–90% FK, 89–60% FK, <60% FK). Only locations obtained when wolves and cattle were both on the DMA (i.e., Jul–Sep) were used for movement analysis.

Wolf Impact on Cattle Populations

Nonradiomarked calf carcasses were found opportunistically by ranchers and examined as described above for collared calves. Wolf-killed calves found by study personnel did not elicit control actions on the wolves, but were compensated for by Defenders of Wildlife (Fischer 1989). However, calves found independently by ranchers did result in control actions in accordance with established guidelines (U.S. Fish and Wildlife Service 1994). We multiplied cause-specific mortality rates of the marked calf population (Trent and Rongstad 1974) by the total number of calves on the DMA (*n* = 688) to estimate the number of calf mortalities that occurred from specific causes during a given year. We calculated detection rates by comparing the estimated number of calves that died from a particular mortality agent to the number recovered on the DMA during the study. Calf mortalities occurring during the grazing season were separated into calves found by study personnel (radiomarked and unmarked cattle found by study personnel on the DMA) and those found by ranchers on the DMA, thus enabling the determination of a detection rate for wolf kills found by ranchers. We calculated detection rates excluding calves found by study personnel within the number of calves found to represent minimum detection rates on the allotment.

RESULTS

Survival

Survival rates of marked calves were high during the 1999 (95%) and 2000 (98%) grazing seasons, with monthly rates for May–November ranging from 0.98 to 1.00. Causes of death for the 13 marked calves were pneumonia (*n* = 4), wolf predation (*n* = 4), coyote predation (*n* = 1), unknown natural mortality (*n* = 2), and fire-related mortality (*n* = 2).

The wolf predation model (i.e., right censoring non-wolf-caused mortalities) provided a complex relationship (Table 1). The first 2 parameters retained were livestock permittee (χ^2 = 8.924, *P* = 0.005) and wolf activity period (χ^2 = 6.584, *P* = 0.01). All marked calves killed by wolves (*n* = 4) were in the Aldous herd, and mortalities occurred when wolves and cattle were interacting (i.e., Jul–Sep). Because these parameters were categorical variables, we simply restricted our analysis to those cattle radiomarked in the Aldous herd (*n* = 211) during the time when wolves and cattle interacted. We restricted our analysis for several reasons: (1) Aldous calves were younger than other permittee's calves (*t* = −10.526, *P* < 0.001); (2) Aldous calves were located closest to wolf core areas; and (3) comparisons of biologically relevant factors affecting wolf selection should occur between calves under similar predation pressure.

Within the restricted data set, the only parameter retained in the model was calf birthdate (χ^2 = 5.04, *P* = 0.025). The coefficient for this parameter indicated that calves born later in the season (i.e., younger) were more susceptible to wolf predation. The rate ratio for the age parameter ($e^{0.046}$ = 1.05) indicated that for each day older, a calf's risk of wolf predation declined by a factor of 5%. Thus, calves 1 month younger than others in their cohort were over 4 times (1.05^{30} = 4.32) more likely to die from wolf predation. On average, the surviving cohort of Aldous calves was 24 days older than that of the wolf-killed cohort (wolf-killed: 31 Mar ± 13 days [mean birthdate ± SE], *n* = 4; live population: 7 Mar ± 1.6 days, *n* = 207).

Space Use

Home-range analysis indicated that as wolf and cattle range size was restricted to defined core use areas, only Aldous calves showed an increase in the percent of overlap with wolves (Fig. 2). Further, only Aldous calves had core areas that overlapped with wolves during the 1999 grazing season. Thus, Aldous calves likely had highest
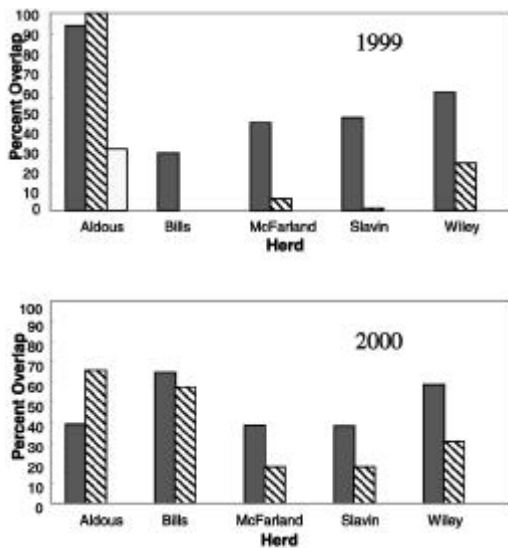
Fig. 2. Percent overlap between cattle and the Jureano wolf pack home range for individual permittees on the Diamond Moose Association. Dark bars indicate 95% (fixed kernel) cattle utilization overlap with 95% wolf utilization, hatched bars are 95% cattle with 50% wolf, and the white bars are 50% cattle with 50% wolf.

exposure to wolf predation risk during the period when wolves were most actively killing cattle.

Only 2 variables influenced calf movement significantly: days to next location ($F = 51.443$, $P < 0.001$) and year ($F = 6.117$, $P = 0.014$). Wolf-predation risk (i.e., wolf use level at the initial calf location, wolf use level at the final calf location, and the amount of wolf use change between locations) did not influence the distance that calves moved per day (all $P > 0.38$). Further, none of these variables were significantly related to calf movement prior to retention of the first 2 variables in the model (all $P > 0.21$). The observed annual variability in calf movement patterns was the result of reduced calf movement in 2000 (629 ± 76 m [mean $\pm$ SE]) relative to 1999 (429 ± 35 m).

Cattle group size was affected by position on slope ($\chi^2 = 13.13$, df = 4, $P = 0.011$) and habitat type ($\chi^2 = 16.16$, df = 6, $P < 0.001$). Larger groups of cattle were observed near riparian bottoms and in more open habitat. Following the retention of these 2 variables in the model, wolf utilization levels were not related to cattle group size ($\chi^2 = 3.04$, df = 6, $P = 0.80$). These results, combined with the aforementioned movement analysis, suggested that wolf predation had little influence on cattle movement or behavior.

Wolf Impact on Cattle Populations

The Jureano Mountain wolf pack was involved in 6 documented calf depredations on the DMA (4 radiomarked, 2 unmarked) during the 2-year study. Based on mortality rates of the marked calf population, we further estimated that wolves killed 16 calves on the DMA during the 2 years of the study (Table 2). Wolf-caused calf mortality detection rates without mortalities found by study personnel were 1 of 8.0 wolf kills (Table 2). Similarly, detection rates for nonpredation mortalities without mortalities found by study personnel were 1 of 11.5 deaths. Because the DMA was grazed by 688 cow–calf pairs each season, we estimated that wolves killed approximately 1.2% (16 estimated wolf kills/1,376 calves) of the calf population each year, while nonpredation deaths accounted for 2.3% of the calf population (Table 2).

DISCUSSION

Survival

Calf survival rates in our study were characterized by low overall mortality during the 1999 and 2000 grazing seasons. No mortalities were observed during 9 of 14 months of the study, and nonpredation mortality rate was higher than that for wolf-caused deaths. The proportion of calves that died from wolf predation during the study versus other causes compared to that found in other studies for wolves (Bjorge and Gunson 1985) and grizzly bears (Anderson et al. 1998).

Other researchers have suggested that wolves select calves over adult cattle (Fritts 1982, Gunson 1983, Bjorge and Gunson 1985, Fritts et al. 1992), although our study appears to be the first to quantify the influence of calf age on vulnerability to predation. Fritts et al. (1992) indicated that as the grazing season progressed, wolf prey selection patterns seemed to favor younger calves disproportionately; our research supports this observation. Wolf prey selection patterns may be explained via active selection by wolves for individuals that are particularly vulnerable due to smaller size or impaired escape abilities. While maternal age and experience may further affect wild ungulate calf vulnerability to predation (Ozoga and Verme 1986, Smith and Anderson 1998, Keech et al. 2000, Berger 2001), at this juncture, we are unable to evaluate the importance of these factors in domestic livestock. Thus, maternal age and experience level, as well as birthdate of calves, should be evaluated more fully as potentially predisposing livestock to wolf predation.

Table 2. Cause-specific mortality rates for livestock calves on the Diamond Moose Association (DMA) in central Idaho, USA. Number of calves dead for each cause was estimated by multiplying cause-specific mortality rate (based on marked population, n = 231) by the total number of calves grazed on the DMA (N = 688). Number missing represents the difference in calf counts from turnout on the range (May) and return from grazing (Oct–Nov), and includes those mortalities found by the study and ranchers.

Mortality cause/ Year	No. found by study	No. found by ranchers	Estimated no. dead	No. missing	Estimated mortality rate (%)[a]
Nonpredation (1999)	6[bc]	1[b]	19		2.8
Wolf predation (1999)	3	2	12		1.7
Coyote predation (1999)	1	0	4		0.6
Total (1999)	10	3	35	28	
Nonpredation (2000)	1[b]	1[b]	4		0.6
Fire (2000)	2[b]	1[b]	8		1.2
Wolf predation (2000)	1	0	4		0.6
Total (2000)	4	2	16	25	
Grand total	14[c]	5	51	53	

[a] Calculated based on Trent and Rongstad (1974): $\{1–[1–(\text{deaths/radio days})^{\text{days}}]\}$. The mortality rates calculated for 1999 were based on approximately 33,696 radio days during a 193-day grazing period, and the mortality rates for 2000 were based on 27,198 radio days during a 170-day grazing period.
[b] One calf found dead was discovered by both study personnel and ranchers.
[c] One calf found dead was unmarked.

Considering the low calf mortality rates we observed, wolves in the study area did not likely subsist exclusively on cattle during our study. Fritts et al. (1992), Bjorge and Gunson (1985), and Tompa (1983) suggested similar conclusions. Cattle, therefore, likely constitute a secondary prey item, which are killed opportunistically by wolves. On several occasions, we observed wolves and cattle in close proximity (<500 m) without witnessing either predatory attempts or clear avoidance behavior. Accordingly, we suspect that predatory interactions occurred infrequently despite the spatial proximity of wolves to cattle.

Space Use

Spatial overlap of cattle herds and wolves likely influenced calf vulnerability to predation. Cattle owned by Aldous had the greatest degree of spatial overlap and wolf predation relative to the other 4 livestock permittees on the DMA. Further, core-area overlap between wolves and individual herds occurred only for the Aldous herd during the 1999 grazing season. Thus, wolf–cattle interactions in the core areas likely resulted in the higher predation rate observed for the Aldous herd during 1999.

Wolf predation risk did not influence cattle movement patterns or group size, suggesting that wolf-caused mortality rates, and/or wolf–livestock predatory interactions were not frequent enough to influence cattle behavior. Large herd size among cattle could increase vigilance levels, thereby providing greater defense for calves (Carbyn and Trottier 1987). The absence of an increase in group size as wolf predation risk increased could be due to several factors: (1) calves on the range had aged sufficiently to reduce the advantage provided by protection versus foraging efficiency, or (2) wolf predation risk was sufficiently low so as not to influence cattle behavior. In light of our results, future efforts should address in greater detail the potential sublethal effect of wolves on livestock movements, weight gain, and productivity across a range of predation risk intensities.

MANAGEMENT IMPLICATIONS

The overall effect of wolves on the calf population within the DMA was not significant. However, managers may need to consider alternative approaches to continued control within areas of persistent wolf depredations. Managers may be able to minimize the spatial overlap of wolves and cattle by implementing a system to move cattle away from wolf core areas during periods of intensive activity. Further, ranchers might reduce their predation losses by releasing the oldest calves on allotments near wolves, although this suggestion requires additional study. Indeed, age may be the most important factor influencing predation in areas of overlap between wolves and cattle.

Carcass detection rates were low in our study, suggesting that current compensation procedures in the western United States may require adjustment to fully cover losses incurred from wolf depredation (i.e., an increased payment for each confirmed wolf-caused calf mortality). Currently, compensation payments result from con-

firmed wolf-killed cattle found by ranchers on an allotment (Fischer 1989). In the case of the DMA, our detection rate data suggest that this method of compensation would result in payment of one-eighth the actual losses to wolves. Although this ratio may be lower (e.g., 1/2) in less timbered or rugged country, it indicates a consistent under-payment of ranchers with wolf depredations occurring on their allotment (Bangs et al. 1998). Indeed, wolf programs in Wisconsin pay for a proportion of missing cattle on ranches where multiple wolf depredations have occurred (A. Wydeven, Wisconsin DNR, personal communica-tion), while compensation programs in Sweden are based simply on the known presence of cer-tain predators and corresponding anticipated losses (D. Smith, Yellowstone National Park, per-sonal communication).

ACKNOWLEDGMENTS

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