IMPACT OF PREVENTIVE AERIAL COYOTE HUNTING ON SHEEP LOSSES TO COYOTE PREDATION

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EFFECT OF PREVENTIVE COYOTE HUNTING ON SHEEP LOSSES TO COYOTE PREDATION

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Abstract: Aerial hunting is commonly used by agriculture agencies in the Intermountain West to reduce coyote (*Canis latrans*) predation on domestic sheep. We assessed the effect of aerial hunting of coyotes on sheep losses to coyotes, and the need for corrective predation management (hours of work, device nights) on the same pastures when sheep arrived for the subsequent summer grazing season (3–6 months after aerial hunting). Comparisons were made between paired pastures with (treated) and without (untreated) winter aerial hunting from helicopters. Average ($\bar{x} \pm$ SE) pasture size was 45.2 ± 14.1 km^2 ($n = 21$) for treated pastures and 30.9 ± 4.6 km^2 ($n = 21$) for untreated pastures. There was an average of $1{,}098 \pm 88$ ewes and $1{,}226 \pm 149$ lambs in treated pastures, and $1{,}002 \pm 149$ ewes and $1{,}236 \pm 79$ lambs in untreated pastures. The number of dead lambs located and confirmed killed by coyotes (confirmed kills) was less in treated pastures (2.7 ± 0.6) than in untreated pastures (7.3 ± 1.6; $P = 0.01$). To estimate total lamb losses to coyotes, we multiplied the proportion of known lamb deaths that were confirmed coyote kills by the number of missing lambs and added the resulting figure to the number of confirmed kills. These estimates of lamb loss to coyotes were also lower in treated (11.8 ± 6.2) than untreated pastures (35.2 ± 8.1; $P = 0.02$). Hours required for summer coyote control also were less ($P = 0.01$) in treated pastures (37.3 ± 8.5) than in untreated pastures (57.2 ± 11.3). Winter aerial hunting increased the mean number of coyotes killed annually per pasture from 2.0 ± 1.0 to 5.7 ± 1.1 ($P = 0.04$), but it did not affect the number of coyotes removed during summer coyote control ($P = 0.52$). Based on 1995 values for Utah lambs and labor, winter aerial hunting of coyotes had a benefit:cost ratio of 2.1:1.

JOURNAL OF WILDLIFE MANAGEMENT 63(2):606–612

Key words: aerial hunting, *Canis latrans*, coyote, livestock, predation, predators, sheep, wildlife damage management.

Coyote predation is a serious problem for livestock producers in the western United States. In 1994, an estimated \$17.7 million in sheep was lost to predators in the United States, with the majority of losses attributed to coyotes (U.S. Department of Agriculture [USDA] 1995). In Utah, Idaho, and Wyoming, 34% of all producer-reported sheep and lamb losses were to coyote predation, which amounted to \$4.8 million in losses during 1995 (USDA 1996*a,b*; USDA, National Agriculture Statistics Service, Idaho Agriculture Statistics Service. 1996. Idaho sheep industry suffers a \$4.26 million death and theft loss, unpublished report. USDA, Boise, Idaho, USA).

Aerial hunting is 1 of many techniques used by wildlife managers to reduce coyote predation on livestock and wildlife (Guthery and Beasom 1977, Sterner and Schumake 1978, Connolly 1981, Stout 1982, Smith et al. 1986). Aerial hunting can be used as a corrective or a preventive management technique. As a corrective technique, coyotes are killed after losses occur, whereas as a preventive technique, coyotes are removed from pastures before sheep arrive (Sterner and Schumake 1978). Preventive aerial hunting typically is used in areas with a history of chronic predation problems or in areas where losses were severe during the prior grazing season (U.S. Department of the Interior [USDI] 1978, Wade 1978). In the Intermountain West, preventive aerial hunting to protect livestock on summer pastures usually occurs from January through March, but sheep are not placed in these pastures until mid-June or July. Critics of this method are concerned that hunting conducted 3–6 months before the sheep arrive may not reduce coyote predation or the need for corrective summer predation management (SPM). Given that areas with aerial hunting are often relatively small and surrounded by areas

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without aerial control (potential source populations), immigration may negate reductions in coyote density by the time the sheep arrive on the summer allotments.

Our goal was to provide information on the costs and benefits of including preventive aerial hunting in a predation management program. If aerial hunting was effective, then we predicted lower sheep losses to coyote predation and lower hours of SPM on treated sites, or no difference in sheep losses but substantially greater hours of SPM on untreated sites. In the latter instance, damage management specialists would be able to keep losses on untreated sites down to the same level as treated sites by spending additional time responding to predation problems on untreated sites. If aerial hunting reduced the hours of SPM, then we also expected a reduction in the number of coyotes killed during SPM. Because techniques used for SPM included traps, snares, and M-44s, which had the potential to injure or kill nontarget species (USDI 1978, USDA 1994), a reduction in the hours of SPM should result in a reduction in the use of these tools and a concurrent drop in the risk to nontarget species.

STUDY AREA

The experiment was conducted from December 1992 through September 1995, and included 3 winter hunting periods (Jan–Mar) and the subsequent summer grazing seasons. We collected data on sheep bands using 30 summer pastures on U.S. Forest Service (USFS) lands in Utah and Idaho and 3 privately owned summer pastures in southern Utah. Three of the pastures on USFS lands were used in 2 years of the study, and an additional 3 pastures on USFS lands were in all 3 years of the study. The pastures on USFS land in Utah were located in the Teasdale and Cedar districts of the Dixie National Forest (NF); the Price, Ferron, and SanPete districts of the Manti-LaSal NF; the Loa and Richfield districts of the Fishlake NF; the Heber district of the Uinta NF; and the Ogden and Logan districts of the Wasatch-Cache NF. In Idaho, we used the Soda Springs and Pocatello districts of the Caribou NF, and the Burley district of the Sawtooth NF. The private summer pastures were located in Iron County, Utah.

Sheep bands grazed these areas from mid-June through the end of September. Sheep in these areas were cared for by a shepherd who remains with the sheep, keeps the sheep band from scattering throughout the pasture, and watches for sick or dead sheep. Fall coyote densities in this area were estimated to range from 0.25 to 0.52 coyotes/km^2 (G. E. Connolly. 1993. Analysis of ADC program impacts on coyote populations on the Richfield BLM district, unpublished report. USDA, Animal and Plant Health Inspection Service, Wildlife Services [WS], Salt Lake City, Utah, USA).

Each year, pastures with aerial hunting (treated) were paired with similar pastures (untreated) that had suitable terrain and sufficient losses to justify aerial hunting, but did not receive treatment for logistical reasons (limited funds, availability of aircraft, conditions unsuited to aerial hunting). Pairings were first based on similarities in habitat, the proportion of area suitable for aerial hunting, and the proportion of rough terrain and understory vegetation. We also made certain lambs in both pastures were of similar age, because the size and age of lambs can affect their vulnerability to predators. Lastly, we paired pastures based on the use or absence of livestock guarding dogs.

To minimize the risk of coyotes moving between untreated and treated areas, we chose a minimum distance of 6.5 km between sites. This distance was twice the average distance between dens and kill sites as determined by Till and Knowlton (1983), and greater than the diameter of a circle with an area equal to the average home range for a subadult coyote as determined by Gantz (1990). Both studies were conducted in habitat similar or adjacent to sites used in our research.

We used 21 pairs of pastures (8 in 1993, 6 in 1994, 7 in 1995) in the study. Average ($\bar{x} \pm$ SE) pasture size was 45.2 $\pm$ 14.1 km^2 for treated pastures and 30.9 $\pm$ 4.6 km^2 for untreated pastures. There was an average of 1,098 $\pm$ 88 ewes and 1,226 $\pm$ 149 lambs in treated pastures and 1,002 $\pm$ 149 ewes and 1,236 $\pm$ 79 lambs in untreated pastures. In 2 instances, we knew sheep in adjacent pastures with the same treatment would be mixed prior to the end of the grazing season. In these 2 instances, data collected from sets of adjacent pastures were combined and treated as if from a single pasture. The area for the 2 sets of combined pastures ($\bar{x}$ = 37 km^2) was similar to the mean area of pastures with 1 sheep band.

METHODS

Numbers of ewes and lambs entering each pasture area were obtained from the livestock producers or by videotaping sheep as they moved past a narrow, fixed observation point. In some instances, the most recent count of ewes and lambs was made several weeks prior to arrival in the pasture. To avoid including losses from this prestudy period in our evaluation, we calculated the ratio (R) of known sheep losses (dead sheep located and cause of death identified [L_k]) to the total number of losses (L_t) for the period from the most recent lamb count to the end of the study season:

$$R = L_k/L_t.$$

We assumed that the ratio of known losses to unknown losses was constant. We then estimated total sheep loss prior to the study (L_p) by using producer records of the number of known sheep losses for the period prior to the study (L_{kp}):

$$L_p = L_{kp}\,R.$$

The estimate of losses prior to the study period was then used to calculate sheep losses during the study period (L_s):

$$L_s = L_t - L_p.$$

Calendars with spaces for the number of ewes and lambs killed by coyotes and by other causes were given to the shepherds to minimize problems with end-of-the-season estimates of predator losses (Robel et al. 1981). We checked with each shepherd every 1–2 weeks to determine if losses had occurred. With the shepherd and livestock producer's assistance, we located dead sheep and, when possible, determined cause of death (confirmed kill) via criteria described by Wade and Bowns (1985). Confirmed loss is the number of dead lambs WS field specialists and study personnel examined and certified as being killed by coyotes. Losses were not attributed to coyotes if there was any uncertainty as to the cause of death.

Because the number of confirmed cases of coyote predation probably underestimates actual loss (Taylor et al. 1979, Scrivner et al. 1985), we estimated total loss to coyote predation (L_{el}) via the following equation:

$$L_{el} = C_{cs} + (C_{cs}/L_{ks})L_{us},$$

where C_{cs} is the number of confirmed coyote kills, L_{ks} is the known number of lamb deaths to all causes, and L_{us} is the number of lambs unaccounted for at the end of the study period.

For each pasture, the WS field specialist recorded the hours of aerial hunting, number of coyotes killed from aircraft, hours of SPM, and the number of coyotes killed during summer work. We calculated "device nights" as a means of quantifying potential risk to nontarget species from traps, snares, and M-44s. One device night equals 1 foothold trap, neck snare, or M-44 set for 1 evening. Therefore, device nights is the sum of the nights that each device was set in the pasture. For each pasture, data on device nights were collected by the WS field specialist working in the area.

We assumed that, in the absence of aerial hunting, there were no differences in lamb losses to coyote predation or in coyotes removed during summer predation management between treated and untreated areas. To test this assumption, we examined pretreatment data (years when neither pasture in a pair received aerial hunting) from Utah WS records for 11 of 21 pairs of areas during 1990–94. For each study pair with pretreatment data, we randomly selected a year when neither pasture received aerial hunting. Data were obtained for that year on the number of coyotes killed during SPM, number of lamb losses to coyote predation confirmed (by WS personnel), and the number of lambs lost to all causes. Data on hours of work (SPM) from the historical dataset were not analyzed, because it was impossible to separate time spent on black bear (*Ursus americanus*) and mountain lion (*Felis concolor*) predation from time spent on coyote predation. Suitable data were not available for 10 of the 21 pairs of pastures.

Data were not normally distributed, and standard transformations of the data did not result in normally distributed data. Therefore, we used the Wilcoxon matched-pairs signed rank test (Seigel 1956) to evaluate differences between treated and untreated areas. Differences were considered significant if $P \leq 0.05$. Data on ewe losses to predation were not analyzed, because coyotes rarely killed ewes (8 confirmed ewe losses for the entire experiment). All means are presented ± standard error.

RESULTS

There were no differences in the size of pasture or the number of ewes and lambs present between areas with and without aerial hunting

Table 1. Comparison of 21 pairs of Utah and Idaho summer pastures during a 1993–95 treatment period when 1 pasture in each pair received aerial hunting (treatment pastures) and the other did not (untreated pastures). Aerial hunting occurred from 1 January to 30 March, and summer work occurred from 15 June to 30 September.

	Treated pastures		Untreated pastures			
Variable	$\bar{x}$	SE	$\bar{x}$	SE	Z[a]	P[a]
Pasture size (km^2)	45.2	14.1	30.9	4.6	−0.26	0.79
No. of ewes present	1,098	88.3	1,002	71.6	−0.89	0.37
No. of lambs present	1,226	148.8	1,236	78.5	−0.46	0.64
Hours of aerial hunting	2.1	0.4				
Coyotes killed by aerial hunting	4.9	1.8				
Summer work (hr)	37.3	8.5	57.2	11.3	−2.58	0.01
Device nights[b]	46.1	13.7	93.9	40.9	−1.78	0.1
No. techniques used in summer	1.1	0.2	1.3	0.2	−0.97	0.33
No. coyotes killed during summer	1.2	0.4	2.0	1.0	−0.65	0.52
Total coyotes killed	5.7	1.1	2.0	1.0	−3.2	0.001
Confirmed lambs killed by coyotes	2.7	0.6	7.3	1.6	−2.79	0.01
Estimated lambs killed by coyotes	11.8	6.2	35.2	8.1	−2.4	0.02
Lambs lost to all causes	52.4	14.3	94.4	17.8	−0.86	0.39

[a] Data were analyzed via Wilcoxon matched-pairs signed rank test (Seigel 1956).
[b] Number of traps, snares, and M-44s used × number of nights they were in use in a pasture.

($P \geq 0.37$; Table 1). Each treated pasture received an average of 2.1 ± 0.4 hr of aerial hunting, with an average take of 4.9 ± 1.8 coyotes or 2.3 coyotes/hr. An average of 0.1 coyotes/km^2 were removed from treated sites (Table 1). All areas had received aerial hunting at least once in the 3 years prior to inclusion in the study.

During the pretreatment period, confirmed lamb loss to coyote predation and lamb loss to all causes did not differ between those areas that later became untreated areas and those that received aerial hunting ($P \geq 0.22$; Table 2). There were no differences in the number of coyotes killed during SPM ($P = 0.72$).

During the treatment period, areas with aerial hunting had fewer confirmed and estimated lamb losses to coyotes ($P \leq 0.02$; Table 1). Estimated coyote losses were reduced from 2.8 to 0.9% of the lambs present in a pasture. Treated pastures also received fewer hours of SPM than untreated sites ($P = 0.01$). However, aerial hunting did not result in a reduction in the number of device nights ($P = 0.10$; Table 1). Aerial hunting increased the total number of coyotes removed from an area ($P \leq 0.05$) but did not reduce the number of coyotes removed during SPM ($P \geq 0.05$).

In Utah, the cost of aerial hunting (helicopter rental, wages for the pilot and WS hunter, ammunition, incidentals) was estimated at $425/hr, and the average cost to keep a WS field specialist supplied and in the field for a year (1,852 hr of work) was approximately $50,000 ($27/hr; Mike Bodenchuk, Utah WS, personal communication). Using data for the average area in our study, we estimated that aerial hunting removed 2.3 coyotes/hr at a cost of $185/coyote, while corrective control removed 0.03 coyotes/hr (data combined from areas with and without aerial hunting) at a cost of $805/coyote (Table 1).

There were 2 direct economic benefits from aerial hunting: (1) a reduction in lamb losses to coyote predation, and (2) a reduction in the hours required for SPM. Based on our data and the cost estimates from above, 2.1 hr ($893) of aerial hunting per area resulted in an average

Table 2. Comparison of 11 pairs of Utah sheep pastures during the pretreatment period (1990–94). During the subsequent treatment period, half the areas received aerial hunting (treated areas) and the others did not (untreated areas).

	Treated		Untreated			
	$\bar{x}$	SE	$\bar{x}$	SE	Z[a]	P
Pretreatment period						
Confirmed lamb losses to coyotes	2.9	1.1	5.4	3.9	−0.41	0.68
Ewes lost to all causes	27.8	11.2	38.1	18.0	−0.84	0.4
Lambs lost to all causes	69.8	19.3	100.0	14.4	−1.24	0.22
Coyotes killed during summer work	1.4	0.7	1.0	0.3	−0.36	0.72

[a] Data were analyzed via Wilcoxon matched-pairs signed rank test (Seigel 1956).

difference of 19.9 hr ($537) of SPM. Using the median difference between treated and untreated sites in estimated lamb losses to coyote predation, we estimated that aerial hunting resulted in a savings of 17.5 lambs/area versus untreated areas. At a 1995 average price of $75.86 for a 45-kg lamb in Utah (USDA 1996*c*), our calculations yeild a savings of $1,328/area; hence, $1,865 of benefits resulted from $893 in expenses, yielding a 2.1:1 benefit:cost ratio.

DISCUSSION

Aerial hunting reduced confirmed and estimated lamb losses to coyote predation despite the fact that aerial hunting occurred 3–6 months prior to the arrival of sheep. Our finding that the percentage of lambs lost to coyote predation was reduced from 2.8% in untreated areas to 0.9% in treatment areas is comparable to a reduction in reported losses of 0.6–1.9% in Idaho (C. J. Packham. 1973. Coyote damage control with helicopters in selected areas of Idaho, unpublished report. U.S. Fish and Wildlife Service, Boise, Idaho, USA). This similarity is noteworthy given that aerial hunting was a preventive technique in our study, and both a corrective and preventive management technique in the Idaho study.

Despite the increase in SPM in untreated areas over treated areas, lamb losses were still significantly higher in untreated areas. This difference in lamb loss indicates the levels of SPM used in this study were not an adequate substitute for aerial hunting. Similar results were obtained in an Idaho study. (C. J. Packham. 1973. Coyote damage control with helicopters in selected areas of Idaho, unpublished report. U.S. Fish and Wildlife Service, Boise, ID, USA) where sites with a 27-day (85%) increase in trapping effort had losses higher than the prior year, but sites with a 39-hr (165%) increase in aerial hunting time had losses lower than the prior year. The difference in lamb loss between sites with aerial hunting and sites with increased SPM may result because SPM techniques were used after coyote predation on livestock had begun and did not prevent the earlier losses, or because aerial hunting was a better means of removing coyotes that had greater likelihood of killing sheep. An alternative explanation for the reduction in SPM at treated sites is that WS specialists believed aerial hunting was an effective tool, and did not check treated areas as often as untreated areas. However, this explanation seems highly improbable because WS specialists generally only check areas after the shepherd or livestock producer has requested assistance. It is unlikely that producers with treated pastures biased results by hesitating to request SPM when they had lamb losses, because, for most livestock producers, each incidence of damage is seen as having the potential to become a long-term predation problem. In Utah, livestock producers paid a set fee to help cover the cost of predation management.

Winter aerial hunting reduced the hours of summer work required. However, there was no difference in the number of coyotes killed during SPM. The lack of difference in the number of coyotes removed during SPM may be attributable to the immigration of new individuals into the treated sites. Given the small size of our study sites, immigration possibly could have resulted in summer coyote densities similar to pretreatment densities. If the odds of capturing the offending coyote are related to the number of individuals present, then the potential similarity in densities may explain the lack of difference in the number of coyotes removed. The immigration of new individuals may also explain the difference in time required per individual captured during SPM. New immigrants are likely to be less familiar with an area and may be more vulnerable to capture techniques like traps and snares than coyotes that are familiar with the area (Windberg and Knowlton 1990). Alternatively, the lack of difference in the number of coyotes killed during SPM may result from the difficulty in finding and killing the specific "offending" individual. Unfortunately, not every coyote removed during SPM may have been killing sheep. The likelihood of capturing additional nontarget coyotes during damage management increases in cases when multiple traps, snares, or M-44s are set, because the "target" coyote(s) may be caught, but the remaining devices can still capture other animals.

If immigration negated the difference in coyote density between treated and untreated areas, then some mechanism other than coyote population reduction is likely responsible for the observed decrease in lamb loss to coyote predation. Alternative explanations for the effectiveness of aerial hunting as used in our study include the breeding pair hypothesis (Till and Knowlton 1983, Messier et al. 1987), the problem coyote hypothesis (Wagner 1997), or a combination of any of the above hypotheses.

The breeding pair hypothesis is based on data from Till and Knowlton (1983) and indicates that many of the spring and summer coyote depredation problems may be caused by territorial adults with pups. Coyote hunting during the early breeding season may disrupt the formation of pairs that can produce young during the subsequent summer. Although continued coyote immigration could result in precontrol coyote densities by the time sheep arrive, lamb losses would still be lower because these new coyotes arrived too late to mate, so there would still be fewer coyotes with pups in the population. The January–March timing of aerial hunting includes the January and February coyote breeding season (Knudsen 1976). The problem-coyote hypothesis assumes aerial hunting removes sheep-killing coyotes that have learned to avoid other corrective control techniques. Data obtained by Andelt et al. (1985) and Windberg and Knowlton (1990) appear to support the hypothesis that vulnerability to control techniques may vary with coyote experience and territoriality.

The lack of significance in device nights may be attributable, in part, to differences among field specialists in skill with or preference for this management technique. Areas with high recreational use are not good candidates for these techniques and, because of the law requiring traps to be checked every 24 hr, WS field specialists may have avoided using traps in areas with limited access.

As used in our study, aerial hunting with helicopters was an effective and economical means of reducing coyote predation. Our calculations of a 2.1:1 benefit:cost ratio are conservative in that we did not include cost of travel time to the areas. The cost of SPM may be higher for large areas or areas with limited vehicle access. With current budget restrictions, WS personnel are often unable to promptly address all requests for WS assistance, and time saved on 1 area with aerial hunting can be spent assisting other producers.

Our data provide evidence supporting the use of preventive aerial hunting of coyotes during winter as a depredation management technique, but caution should be used when extrapolating these data to other situations. This study was conducted under a relatively narrowly defined set of environmental conditions. Changes in terrain, coyote density, aircraft, hunting technique, and the intensity or timing of aerial hunting may affect results. Without an understanding of the mechanisms which make aerial hunting effective, we cannot fully use the potential of this technique.

MANAGEMENT IMPLICATIONS

Preventive aerial hunting from helicopters in winter can be an effective means of reducing sheep losses to coyote predation on summer pastures in mountainous areas. It also appears to reduce the subsequent need for corrective predation management during summer, which can involve the use of traps, snares, and M-44s. Given that preventive aerial hunting was effective in this study with a 3–6-month period between aerial hunting and the arrival of sheep in the pastures, it seems likely it would be effective for situations with shorter periods between aerial hunting and sheep grazing. However, care should be taken when extrapolating these results to other forms of preventive predation management, as the cost of the program and the rate of coyote kills will be influenced by the type of aircraft used, the skill of the pilot and hunter, and weather conditions. Although aerial hunting is effective in reducing sheep losses to predation and the need for summer predation management, decisions on the use of this tool depend on the values and concerns of all stakeholders.

ACKNOWLEDGMENTS

Funding for this study was provided by the Intermountain Region of the USFS, the USDA, WS, the Jack H. Berryman Institute for Wildlife Damage Management at Utah State University, and the Utah Agricultural Experiment Station. Special thanks go to the Utah and Idaho WS personnel for assistance with data collection, and the 31 livestock producers and their families who participated in this study. We also thank J. A. Bissonette, F. F. Knowlton, L. G. McNeal, W. F. Porter, and R. H. Schmidt for their review of this manuscript. This study was part of a doctoral dissertation completed at Utah State University (Wagner 1997).

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Received 19 May 1997.
Accepted 12 September 1998.
Associate Editor: Porter.