EFFICACY OF DENNING IN ALLEVIATING COYOTE DEPREDATIONS UPON DOMESTIC SHEEP

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Abstract: Bands of domestic sheep lambing on the open range in south central Wyoming were monitored for predator losses before and following coyote (*Canis latrans*) removals. Experimental treatments, including (1) no removal (control), (2) removal of 2 adults and their pups, and (3) removal of pups only, were replicated 15 times each. Predation incidents (events) declined 98.2% and the number of sheep killed was reduced by 98.8% when adults and pups were removed. Removing only litters of pups resulted in a decrease of 87.7% in predation incidents and total kills decreased 91.6%. Overall, 23 of 30 predation sequences terminated immediately, whereas in all instances predation ceased within 3 days after removing adult coyotes, their pups, or both. In terms of "offending individuals," denning can be a selective means of coyote depredation control. Removing only litters of offending adults can be nearly as effective in stopping losses as removing the adults. Litter size did not appear to influence kill frequencies. A cost-effectiveness analysis is presented.

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Depredations by coyotes on domestic sheep result in greater losses of domestic livestock than any other predator–domestic prey interaction in the western United States (Balser 1974). Although several techniques used to alleviate such losses have been subjectively ranked with regard to efficiency, selectivity, and other factors (U.S. Dep. Inter. 1978*a*), there are few quantitative data concerning the efficacy of any method. A critical response (West. Reg. Coordinating Comm., WRCC 26, 1980) to a recent policy change for predator control (memorandum from C. D. Andrus to Assistant Secretary for Fish, Wildlife, and Parks, 8 November 1980) accentuates the need for objective evaluation of coyote control methods. Our study attempted to determine the efficacy of "denning," the practice of seeking out the dens of depredating coyotes and destroying the young, adults, or both in stopping depredations upon sheep.

Denning has been criticized for being "unselective" in terms of individual animals (Defenders Wildl. 1978, Sierra Club 1978, Humane Soc. 1978) and removal of individuals that obviously are not responsible for depredations. One author maintains that denning is solely a means of coyote population reduction (Gier 1968).

Experienced predator control field personnel claim that denning can be a selective method for resolving specific depredation situations. Conceivably, predation on domestic sheep by adult coyotes can be influenced indirectly by removal of litters as opposed to removal of the adults actually killing sheep. Anderson (1969:513–514), among others, believes predation should cease when pups are destroyed. Absence of quantitative data leaves these questions unanswered.

Cain et al. (1972) recommended cost–benefit analyses of predator control methods, stating that such information was yet to be collected. Because most depredation control programs consist of several methods applied simultaneously, the effectiveness of a single control method is difficult to determine (U.S. Dep. Inter. 1978*a*). Because no other control methods were in effect during the present study, except winter removal for fur, the opportunity

was available to measure the cost and effectiveness of denning alone.

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STUDY AREA

Fieldwork was conducted in south central Wyoming during April, May, and June 1980 and 1981, and was concentrated in the eastern half of Carbon County. About 20,000 sheep lamb on the open range with sheepherders in attendance. Spring lambing range is used until late June when sheep are moved onto mountain summer range. Lambs are generally shipped in late September or October. The study area (approximately 2,600 km^2) averages 2,000 m elevation; dominant vegetation consists of big sagebrush (*Artemisia tridentata*) and western wheatgrass (*Agropyron smithii*). The topography, vegetation, climate, and sheep husbandry practices in this area have been described by Tigner and Larson (1977).

METHODS

Sheep killed by coyotes were located and reported to us by sheepherders. Upon receiving a report, we went to the area, examined all carcasses, and conducted necropsies to verify the cause of death. Puncture wounds with attendant hemorrhaging were used as evidence of predation (Rowley 1970, Bowns 1976). To meet test conditions, a threshold of predation defined as 3 sheep killed in at least 2 incidents during 1 week was required. If this threshold was attained and other predator control methods were not in effect (nor anticipated), the particular band of sheep was included in this study.

Once test conditions were met, 1 of 3 treatments was randomly chosen and applied: (1) no coyote removal (control); (2) removal of "offending" adult coyotes (individuals killing sheep) and their litters; and (3) removal of the complete litter but not the depredating adults. Depredations were monitored for 7 days following completion of a treatment. Each treatment was replicated 15 times.

Coyote dens were located by tracking adult coyotes away from sheep kills (Young and Dobyns 1945). Adult coyotes were shot at or near the den sites for treatment #2. Stomach samples from adults were examined in the field for sheep or other animal remains. Pups were destroyed in the dens with a fumigant described by Tigner and Larson (U.S. Dep. Inter. 1978*b*). Fumigated dens were excavated and pups counted and weighed. Ages of pups were estimated by tooth eruption patterns (Bekoff and Jamieson 1975). A thorough search of the den area was made for animal remains. Den sites were plotted on a map for density determination as well as den locations in relation to depredation area. In replications of the no-removal (control) treatment, dens were not approached or disturbed.

Efficacy was assessed on the basis of changes in both the number of depredation incidents (number of times the flock was attacked) and the number of sheep killed in the week after treatment compared with the week preceding. Kruskall-Wallis, Wilcoxon Signed Rank, and Wilcoxon Rank Sum tests (Ott 1977) were used to compare number of incidents, number of kills, and changes in each as a result of treatments.

Cost–Benefit Analysis

The cost-effectiveness analysis was based on field seasons combined and the following assumptions:

1. The monitoring intensity did not change during pretreatment and post-treatment periods. Therefore, the proportion of coyote-killed sheep that were located was probably constant.
2. The number of sheep killed prior to coyote removal treatments accurately reflected the number that would have been killed had treatments not been applied. This assumption was supported by the kills documented in the control.
3. The wages, expenses, and field time of personnel were reasonable for this region.
4. The number of sheep saved does not necessarily represent the absolute number that would be sold as 45.4-kg (100-lb) fat lambs in the fall. Low mortality during summer is expected; however, we believe that this level of mortality is insignificant compared with the number of lambs killed by coyotes and not located during the experiment. In addition, all surviving lambs will not weigh 45.4 kg at shipping, and depending on various factors, some ewe lambs are retained for herd replacements. We believe these conservative loss figures serve as a baseline for estimating the point at which a denning program may become cost-effective.

RESULTS

In the no-removal treatment, the pre- to post-treatment change in numbers of incidents and kills was −4.2%. Pre- and post-treatment numbers were not different for incidents ($T = 9$, $N = 6$, $P < 0.05$) or kills ($T = 34$, $N = 12$, $P < 0.01$). In addition, no differences ($\chi^2 = 6.89$, df = 3, $P < 0.05$) could be shown in total incidents, or in total kills ($\chi^2 = 2.55$, df = 3, $P < 0.05$) when pre- and post-treatment periods of the no-removal (control) treatment were compared with the pretreatment periods of the removal treatments (Fig. 1).

In replications where adults and pups were removed, the number of post-treatment depredation incidents was reduced 98.2% from pretreatment levels (Table 1). The number of post-treatment incidents ($\bar{x} = 0.1$) was different ($z = 4.98$, $P < 0.001$) than the number of pretreatment incidents ($\bar{x} = 3.7$). Following removal of adults and pups, the number of kills observed declined 98.8%. The number of post-treatment kills ($\bar{x} = 0.1$) was different ($z = 4.93$, $P < 0.001$) from the number of kills observed pretreatment ($\bar{x} = 5.3$).

Depredation incidents were reduced 87.7% following removal of pups only (Table 1). Among the 15 replications, the number of post-treatment incidents ($\bar{x} = 0.5$) differed ($z = 4.81$, $P < 0.001$) from the number of pretreatment incidents ($\bar{x} = 3.8$), the number of kills observed pretreatment ($\bar{x} = 5.5$) was reduced 91.6% and differed ($z = 4.75$, $P < 0.001$) from the number of post-treatment kills ($\bar{x} = 0.5$) after only litters were removed.

In 8 of 15 replications, killing stopped immediately after removing only the pups of offending adults. In each of the other 7 replications, 1 additional lamb was killed within 3 days after removing coyote litters. No killing occurred during post-treatment days 4 through 7.

Collectively, treatments involving removal of adult coyotes, their pups, or both were documented in 30 replications. In 22 of the 30 (73%), killing was stopped immediately; depredations were terminated in all replications 3 days following treatment.

Biological Data

Litter size, weight, or age of pups, and the distance between kill sites and the den appeared to have little influence upon the total number of sheep killed, or the rate

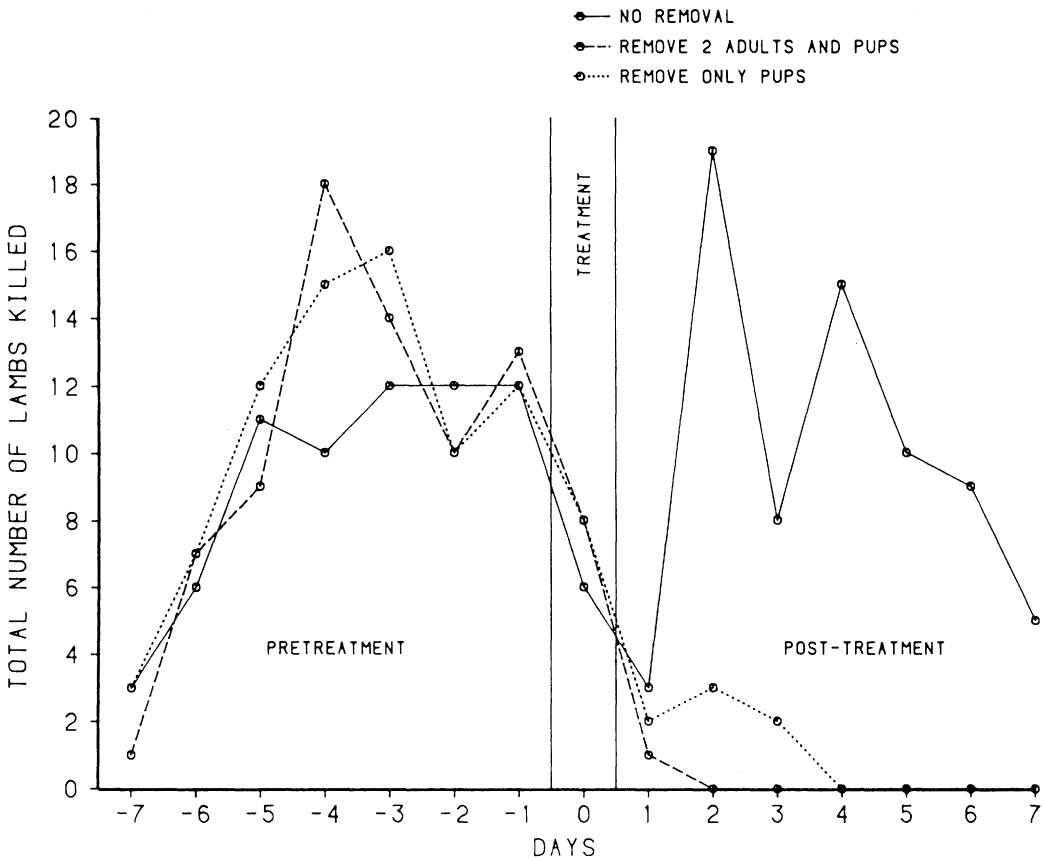

Fig. 1. Total sheep kills, before and after 3 coyote removal treatments, south central Wyoming, 1980–81.

Table 1. Number of depredation incidents, sheep killed, and percent change in the 7 days before and after each of 3 coyote removal treatments, south central Wyoming, 1980–81.

Removal treatment	N	Pretreatment period				Post-treatment period				Percent decrease
		Total	$\bar{x}$	SD	Range	Total	$\bar{x}$	SD	Range	
Depredation incidents										
No coyotes (control)	15	48	3.2	0.9	2–5	46	3.1	1.1	2–5	4.2
Pups and 2 adults	15	56	3.7	1.0	3–6	1	0.1	0.3	0–1	98.2
Pups only	15	57	3.8	0.8	2–5	7	0.5	0.5	0–1	87.7
Subtotals (removals)	30	113	3.8	0.9	2–6	8	0.3	0.4	0–1	92.9
Sheep killed										
No coyotes (control)	15	72	4.8	1.6	2–7	69	4.6	2.1	2–9	4.2
Pups and 2 adults	15	80	5.3	2.2	3–9	1	0.1	0.3	0–1	98.8
Pups only	15	83	5.5	1.6	3–9	7	0.5	0.5	0–1	91.6
Subtotals (removals)	30	163	5.4	1.9	3–9	8	0.3	0.4	0–1	95.1

at which they were killed. The average distance from the site of depredations to the den was 3.25 km (range 1–10 km). Animal remains were found at 77% of the dens examined. Sheep remains were found in 9 of 31 (29%) adult stomach samples.

During our study, the density of dens of depredating coyotes averaged at least 1 den/70 km^2; 1 area of 80 km^2 contained 5 dens in 1981. These densities are minimal spring den densities; total coyote density was not estimated. Whether the ready availability of large numbers of domestic lambs resulted in a high density of coyote dens is conjectural.

Cost-effectiveness Analysis

The average salary for a U.S. Department of Interior Animal Damage Control den hunter in Wyoming is $1,020.00/month plus $650.00/month in expenses (F. Christensen 1980, pers. commun.). Expenses include vehicle maintenance and gasoline, per diem, and miscellaneous items such as horse rental. Therefore, $1,670.00/month was used in this analysis. Field personnel are involved in den hunting from 15 April until 1 July (2.5 months or 75 days). Total expenses were calculated as: $1,670.00 × 2.5 months × 2 years = $8,350.00.

During the 2 field seasons, 40 dens of depredating coyotes were located and destroyed in about 5 months for an average of 0.27 dens/day, or roughly 2 dens/week.

Exact prices are variable, but it seems reasonable to use a 5-year (1977–81) average of $57.74/cwt for fat lambs marketed in October as a realistic and accurate value of lambs lost to coyotes. This, of course, assumes that coyote-killed lambs would survive to shipping; however, as acknowledged in assumption #4, this possible overestimation of values is probably outweighed by other factors. Given that a value of $57.74/lamb is reasonable and that total expenses incurred amount to $8,350.00, the following formulae should estimate when the program becomes cost-effective. The average expense to locate and remove 1 den of offending coyotes was $8,350.00/40 = $208.75. This average divided by the average value of 1 lamb should estimate the number of lambs it would be necessary to save to recover costs (on a per den basis): $208.75/$57.74 = 3.62 lambs. The average number of lambs killed per week is calculated as the total number of kills observed in the control treatment, plus all pretreatment kills observed in removal treatments, divided by the number of "den weeks" (i.e., 7-day predation sequences attributable to 1 den), or 345/70 = 4.93. We assume that an average of 4.93 lambs would be killed in an average 7-day period. The determination of a time period when costs are recovered is calculated by dividing the average number of lambs required to break even (3.62) by the average number of lambs killed per week (4.93), which equals 0.73 week. Provided these rates of predation and den removal are reasonable, only 0.73 × 7 = 5.1 days are necessary to recover costs.

DISCUSSION

Adult coyotes may initiate and continue depredations on domestic sheep during the pup-rearing season as a means of maximizing their hunting efficiency. Royama (1970) implied adult predators may do this by feeding their young more "profitable" prey items than they consume themselves. Domestic lambs are possibly the most "profitable" prey items available to coyotes at this time of the year because they are abundant, easily preyed upon, and larger than most prey. Additional credence to the hypothesis that coyotes select for "profitable" prey when feeding a litter of pups may be gained by considering the

relatively great distances adult coyotes will travel to obtain domestic lambs (Young and Jackson 1951, Lemm 1973), when less "profitable" (i.e., smaller, less abundant, and more difficult to capture) prey items are found nearer the den. When pups and their attendant energy demands are eliminated, it is no longer necessary for adults to maximize hunting efficiency and depredations on lambs should be less intense.

Learned predatory behavior is another factor that influences depredations by coyotes on spring lambing ranges. The extent to which this factor governs total losses is speculative, as all adult coyotes raising litters in lambing areas may not kill lambs. The predilection of some coyotes for lambs encompasses more than a simplified model pertaining to a maximization of the available prey resource.

Most predator losses occurred before docking, when the first accurate count of range-born lambs is made. Because it is virtually impossible to account for all lambs born (Tigner and Larson 1977) and for all mortality (Bowns 1976, Nass 1977), the percent of each bands' lamb crop lost to coyotes was not estimated. Klebenow and McAdoo (1976) stated that were it not for their efforts in monitoring losses, sheepherders would have found less than half of the losses that occurred. Losses resulting when coyotes killed and carried small lambs away from the main band were not accountable. Consequently, in our study, additional depredations may have occurred that were not observed. Adjustments for such inaccuracies were not made. The loss figures must be assumed minimal; total predator losses must be somewhat greater.

The cost-effectiveness analysis we calculated is short-term essentially relating the immediate benefits of removing offending adults, their pups, or both in particular predation situations. Because predation may continue relatively unabated unless the sheep are moved, total losses inflicted by a pair of coyotes provisioning pups could be severe if control measures were not implemented. Although lamb losses to coyotes are generally highest in the spring, another major predation period during the late summer or early fall has been noted (Klebenow and McAdoo 1976, Tigner and Larson 1977, Boggess et al. 1980). Field personnel assert that fall predation is related to learning and development of sheep-killing behavior in pups. Lamb losses to coyotes just before shipping are most damaging financially since the cost of production is nearly complete and returns have yet to be realized. The depredation reduction gained by removing a pair of offending coyotes or their pups from certain areas is potentially many times greater than that observed immediately, although it is as yet uncertain whether adults lacking pups will initiate depredations in the fall. Long-term data sets of predation sequences under these circumstances are nonexistent. To assume that denning is cost-effective in all conditions probably is inappropriate.

MANAGEMENT IMPLICATIONS

Wagner (1972:37) stated that some data suggest depredations are reduced following generalized coyote population reduction. However, he continues "the evidence on total sheep losses shows little, if any, correlation with density." Denning is considered by some (including Gier 1968) to be a means of coyote population reduction, although others doubt its effectiveness (U.S. Dep. Inter. 1978*a*). When considering relatively small areas such as lambing ranges, it is possible that pup removal may effect a temporary population reduction. If a population reduction of offending family groups extends past normal lamb shipping dates, a fall predation

peak may not occur. The effect of such reduced densities on the more mobile part of adjacent coyote populations has not been measured, but removing only pups may significantly reduce fall depredations.

Because this research indicates that depredations upon domestic sheep can be alleviated by removing litters of offending adult coyotes, one might wonder about situations where no pups are born. Coyotes are territorial around a den (Camenzind 1978, Bowen 1982); whether they remain so if pups are removed, or if the female fails to conceive after a pair bond is formed and a territory established, is not known. Theoretically, without pups, depredations by coyotes should be less. If such coyotes will continue to defend territories, excluding others, it is interesting to speculate about the efficacy of reducing depredations on areas with chronic losses, such as lambing ranges, by sterilizing resident adult coyotes.

The contention that it is better to leave non-offending coyotes in livestock areas than coyotes that may or may not cause problems has been mentioned by Boggess et al. (1980). As demonstrated in our study, the status of offending adults can be changed by removing their pups in the spring. An important and selective preventative control method might be gained by manipulating the mechanism (cause) that may trigger depredations. Extensive studies might determine if a long-range behavioral change can be effected. Our research has documented the results of manipulation after the fact; further research should probe the efficacy of selectively preventing depredations. Future research may provide alternatives to denning in resolving coyote depredations, recognizing the need for both livestock protection and the aesthetic and economic value of coyotes.

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