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Preventive Predation Management: An Evaluation Using Winter Aerial Coyote Hunting in Utah and Idaho

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PREVENTIVE PREDATION MANAGEMENT: AN EVALUATION USING WINTER AERIAL COYOTE HUNTING IN UTAH AND IDAHO

by

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ABSTRACT

Preventive Predation Management: An Evaluation Using

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by

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To evaluate preventive aerial coyote hunting as a depredation management technique, I compared sheep losses to coyote (Canis latrans) predation and the hours of corrective predation management required on summer grazing areas with and without hunting the prior winter from helicopters. Correlations were used to test for relationships between the extent, intensity, and timing of aerial hunting and lamb losses to coyote predation. Data on the age, sex, and reproductive status of coyotes killed using aerial hunting, traps, snares, and calling-and-shooting were used to test for differential coyote vulnerability to damage management tools, and to assess the impact of aerial hunting on coyote populations.

Winter aerial hunting reduced confirmed and estimated lamb losses to coyote predation and the hours of effort required for corrective predation management the subsequent summer. Aerial hunting increased the number of coyotes killed annually per grazing area, but did not reduce summer coyote removal. There were no consistent relationships between the extent, intensity, or timing of aerial hunting and sheep losses to coyote predation. The male: female ratio for coyotes captured with calling-and-shooting was higher than that for traps or aerial hunting. More juvenile coyotes were killed with aerial hunting than with traps or shooting. However, there was no difference in the age of adult coyotes (>1.5 years old) removed using any control method or between the age of coyotes from areas with and without consistent aerial hunting. Confounding factors in the data and the high number of uncontrolled variables prohibited clear identification of the mechanism making aerial hunting effective.

I also examined financial compensation programs as an alternative to lethal control. Nineteen states and 7 Canadian provinces had compensation programs. Compensation programs appeared to be established when wildlife problems were of recent origin, resulted from government actions, and/or were caused by highly valued species. Compensation programs for coyote damage had been established in 4 states/provinces in eastern North America where coyotes are a new problem, but are unlikely to be a acceptable tool for the western U.S.

(110 pages)

Dedicated to my family for their love and support, and for believing in my dreams even when I had doubts....

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Kimberly K. Wagner

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CHAPTER 1

INTRODUCTION

Coyote (Canis latrans) predation is a serious problem for livestock producers in the western U.S. In 1994, an estimated $17.7 million in sheep (Ovis aries) were lost to predation in the U.S., with the majority of losses attributed to coyotes (USDA 1995). In 1995, woolgrower estimates of sheep and lamb losses to coyote predation were 34% of all estimated sheep and lamb losses, and 63% of estimates of sheep and lamb losses to all predators, a loss of $1.6 million per state in Utah, Idaho, and Wyoming (USDA 1996a,b,c).

The damage management techniques used to reduce coyote depredations can be classified as being preventive or corrective methods. Corrective techniques focus on stopping predation once it has started. In contrast, preventive techniques attempt to keep losses from starting by making the sheep less vulnerable to predation (shepherds, livestock guarding dogs, penning the sheep at night, etc.), and/or removing coyotes from areas used by sheep (traps, aerial hunting etc.; Wagner 1988). Although there is some level of opposition to any lethal management technique, lethal preventive control methods are especially controversial because they are perceived to focus on reducing coyote populations instead of removing individual "offending" coyotes that kill sheep. Critics are concerned that these techniques may be killing "innocent" coyotes that are not part of the predation problem. Despite the controversy, there are relatively few studies assessing the effectiveness of lethal preventive control. This is especially true for aerial coyote hunting, the primary lethal preventive depredation management technique currently in use.

Most evaluations of preventive control involve the use of the predicides. The results of these studies are mixed. An early study by Robinson (1948) supported the use of poison meat baits, reporting an 87% average reduction in producer reported loss. U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service, Animal Damage Control (ADC) records of sheep loss for Utah, Idaho, Wyoming, and Colorado indicated a decline in the late 1940's, the beginning of extensive poison bait use, and low losses through the 1960's

(Wagner 1988). Likewise, producer reports to the USDA Forest Service of sheep losses during the summer grazing season also showed a decline in the late 1940's. However, these loss reports steadily increased until they had reached pre-decline levels by 1970 (Wagner 1988). If predicides had reduced sheep losses to coyote predation, there should be an increase in losses starting after the 1972 predicide ban by President Nixon. However, several authors have reviewed USDA Statistical Reporting Service (SRS) and Forest Service data and concluded that losses to coyote predation in most states have either remained level or slowly increased from 1956-1978 (Gee et al. 1977, Lynch and Nass 1981, Wagner 1988).

Wagner (1988) described lethal preventive control methods as techniques designed to reduce coyote populations with the assumption that sheep losses are directly related to coyote density (hereafter referred to as the population control hypothesis). According to Wagner (1988), 3 basic assumptions must be met for preventive control to be effective: (1) there must be a correlation between coyote population density and sheep losses, (2) the control technique must significantly reduce coyote population levels, and (3) sheep losses to coyote predation must not be a compensatory form of mortality (Wagner 1988). Some evidence of a positive correlation between coyote density and sheep losses to coyote predation exists from areas with differing coyote densities (Shelton and Klindt 1974, Robel et al. 1981, Wagner 1988) and for a single site in years with differing coyote densities by L.C. Stoddart and R.E. Griffiths (USDA Predator Ecology Center, Changes in jackrabbit abundance affect predation on sheep in southeastern Idaho, Logan, UT, 1986).

Most evaluations of the ability of a control technique to reduce coyote populations involve the widespread use of predicides. If predicides had reduced coyote populations, then populations should have increased during the period after the 1972 predicide ban. Population data obtained from scent post indices for the period of 1972-1980 indicated little to no change in coyote population indices during this period (Linhart and Knowlton 1975, Roughton and Sweeny 1982, Wagner 1988). This lack of change may also have been attributable to increased use of alternative methods for killing coyotes (Evans and Pearson 1980). Data from Evans and Pearson (1980) for 13 western states for the period of 1971-1972 indicate that there was little or no decline in coyotes killed by ADC operations after the predicide ban.

If coyote predation is a compensatory form of sheep mortality, then sheep that would have been killed by coyotes should be otherwise lost to illness, injury, or depredations by predators filling the "space" left by coyote removal. In studies of sheep behavior relative to coyote predation (Gluesing et al. 1980, Blakesley and McGrew 1984), sick and injured sheep, and new additions to sheep flocks were often found trailing behind and at the edges of sheep flocks. Sheep at the periphery of flocks appeared to be more likely to be attacked than sheep in the main body of the flock (Gluesing et al. 1980, Blakesley and McGrew 1984). However, the survivorship of these ewes and lambs in the absence of predation is unknown. In a study by O'Gara et al. (1983), the proportion of lambs having zero, minor, or severe physical deformities in a sample shot from the center and periphery of a sheep band by biologists was not substantially different from the same ratios calculated for lambs killed by coyotes. The authors concluded that there was no evidence for a coyote preference for healthy or sick sheep (O'Gara et al. 1983). With the exception of foxes (Vulpes and Urocyon spp.) that prey on very small lambs, it seems unlikely that coyotes have the ability to exclude the other mammal species primarily responsible for sheep depredations (e.g. mountain lion [Felis concolor], and black bear [Ursus americanus]).

The 2 alternative hypotheses on the effectiveness of lethal preventive predation management differ from the traditional population control hypothesis in that a reduction in local coyote populations can occur but is not necessary. The first prediction is that aerial hunting is effective because it disrupts breeding (breeding pair hypothesis; Till and Knowlton 1983, Messier et al. 1987). Till and Knowlton (1983) speculated that much of the spring and summer coyote depredation problems may be caused by territorial adults with pups. In their study, coyotes were tracked back to their dens from depredation sites and either the adults and pups, or the pups were removed. In the week following removal, depredation incidents were reduced 98% when adults and pups were removed and 88% when only pups were removed. In all cases, depredation ceased within 3 days of coyote removal. Given this information, techniques that reduce the number of adults with pups should significantly reduce sheep losses to predation. This could be accomplished through denning, the development of contraceptive techniques, or by disrupting breeding through the removal of one or both members of a pair. In the latter instance, coyote removal would have to be timed so that there would be insufficient time for new breeding pairs to become established before the end of the subsequent breeding season.

The second hypothesis predicts that some preventive control techniques capture coyotes that are less vulnerable to corrective control techniques (problem coyote hypothesis; U.S. Department of the Interior [USDI] 1978, Wade 1978). Personnel working with coyote predation management assert that coyotes can learn to avoid techniques like trapping and calling-and-shooting (Wade 1978), making it important for managers to have a variety of techniques available (USDI 1978, USDA 1994). Data obtained by Andelt et al. (1985) and Windberg and Knowlton (1990) support the hypothesis that vulnerability to control techniques may vary with coyote experience and territoriality. Some techniques are available for preventive control that are not always available for corrective control. For example, in the Intermountain West, winter aerial coyote hunting from aircraft is used as a preventive control technique for summer grazing pastures. Plant foliage, and less stable warm air prohibit the effective use of this technique during the summer, so preventive aerial hunting allows managers to try an extra technique. If a coyote's ability to avoid control methods is related to age (experience), then preventive control may also be valuable because it reduces the age of a population. Most new territory holders are likely to have been nonterritorial juveniles and yearlings (Knowlton 1972, Camenzind 1978, Gese et al. 1988). Therefore, if the preventive control technique removes a substantial proportion of the older coyotes, there should be a decline in the average age of coyotes remaining. This decrease in age (experience level) of the population may result in a decrease in the time or effort required to correct predation problems.

Aerial hunting is one of the few preventive control techniques still used by the ADC program. It is one of the most efficient (coyotes/unit time) means of killing coyotes, especially in areas with limited access or rough terrain (J. H. Berryman, USDI Wildlife Services, unpubl. rep; USDI 1973a, b; Sterner and Schumake 1978; Wade 1978). During aerial hunting, trained teams of pilots and hunters seek and shoot coyotes from low-flying aircraft. Both fixed-wing aircraft and helicopters are used for aerial hunting. Although more expensive, the increased maneuverability of helicopters is necessary for areas with rough terrain, including most of the USDA Forest Service (USFS) summer grazing allotments of the Intermountain West. Preventive aerial hunting is used in areas with chronic predation problems and in areas where the previous grazing season's losses were severe (Wade 1976, 1978; USDI 1978). In federal fiscal year 1996, 391 coyotes were killed by the ADC program using helicopters in national forests in Utah during preventive aerial hunting programs. (Utah ADC, unpubl. data).

This study focused on winter aerial hunting with helicopters as a preventive depredation control technique, in part because of the need for additional data on the efficacy of preventive aerial hunting. Only 2 studies have evaluated preventive aerial hunting (C.J. Packham, USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973; T. E. Anderson, M. Caroline, and J. L. Beavers, USDI Wildl. Serv., An evaluation of aerial hunting as a means of protecting sheep and goats from coyote and bobcat predation in Uvalde and Kinney Counties, Texas, Albuquerque, NM, 1974). However, both studies are of limited value because they used aerial hunting as a preventive and a corrective management technique, making it impossible to differentiate between the impact of preventive and corrective aerial hunting. In Texas, aerial hunting did not result in a reduction in sheep losses to coyote predation. However, the authors noted that plant foliage prevented efficient predator location, and better results might have been obtained if control was conducted in winter when foliage was absent (T. E. Anderson, M. Caroline, and J. L. Beavers, USDI Wildl. Serv., An evaluation of aerial hunting as a means of protecting sheep and goats from coyote and bobcat predation in Uvalde and Kinney Counties, Texas, Albuquerque, NM, 1974). Lack of replication in the Texas study also prohibits extrapolation of this information to other management situations.

In a study conducted by C.J. Packham (USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973), aerial hunting was compared to ground control techniques when both were used for corrective and preventive management. Preventive aerial hunting was conducted from 1-12 weeks before lambing but preventive ground control was conducted during the fall prior to the lambing season. Both areas received corrective control as needed. A combined 39-hr (165%) increase in aerial hunting and 3.5-day (2.3%) increase in ground control resulted in lamb losses that were 34% of the prior year's losses. However, the 27-day (84%) increase in trapping effort in similar areas without aerial hunting resulted in lamb losses 131% higher than in the prior year. The study did have some replication (4 treated areas, 2 control areas), but the differences in the time between the two types of preventive control and lambing and in the magnitude of increase in control effort (165% vs 84%) make it difficult to compare between techniques. Additionally, the time between preventive control and sheep arrival in this study (1-12 weeks) was less than that commonly found between preventive control and sheep arrival on summer grazing allotments of the Intermountain West (3-6 months).

Critics of the preventive winter aerial hunting program expressed concern that coyotes preying on sheep during the summer grazing season might not remain in the area throughout the year. Deer and elk, a potential food supply, migrate to lower elevations during the winter months, and critics hypothesized that the coyotes would follow the prey (Gantz 1990). If true, this would have made it virtually impossible to identify and remove coyotes associated with depredation problems in a particular summer grazing area. Gantz (1990) was able to obtain data on seasonal movement patterns from 2 adult, 4 yearling, and 5 juvenile coyotes with radio collars in the Bear River Mountains of Utah and Idaho. Coyote movement patterns were recorded from 13 November 1987 to 15 September 1989. There was no evidence of seasonal movement from mountain to valley locations. Although there is evidence of seasonal changes in home range size, additional studies on coyote movements also support the belief that coyotes usually remain within their territories throughout the year (Hibler 1977, Camenzind 1978, Laundre and Keller 1981, Beckoff and Wells 1982).

Information is available on the use of preventive aerial hunting to improve fawn survival in pronghorn antelope (Antilocapra americana) and deer (Odocoileus spp.). Smith et al. (1986) evaluated a program using helicopters to remove coyotes from spring pronghorn ranges just prior to fawning season. In their study, 3 years of aerial hunting resulted in an average of 57 fawns/100 does, in contrast to an average of 31 fawns/100 does during years when only trapping was used. Smith et al. (1986) developed a model to determine the benefit:cost ratio of various aerial coyote hunting schedules and suggested a 1.92 benefit:cost ratio for control used every other year. Studies using other techniques for preventive predation management appear to support findings that predator removal can enhance pronghorn populations (Arrington and Edwards 1951, Udy 1953). Some studies using aerial hunting to improve deer (Odocoileus virginianus) productivity in Oklahoma (Stout 1982) and South Texas (Guthery and Beasom 1977) have resulted in improved fawn survival. However, the results of programs using preventive control to protect deer (O. hemionus and O. virginianus) have been highly variable (Connolly 1981). The program success appears to depend on herd size relative to carrying capacity, coyote population size relative to deer herd size, availability of alternate prey, and the impact of the control program on the predator population (Connolly 1981, Hobson 1990).

Data assessing the costs and benefits of aerial hunting are also limited. An informal survey of 11 states using aerial hunting revealed these programs cost $148,929 in 1970 while the estimated cost of using ground control for the same work was $614,845 (J. H. Berryman, USDI Wildlife Services, Washington, D.C., unpubl. rep, 1971). One year's work in damage management alternatives was estimated to equal 87 hrs of flying (J. H. Berryman, USDI Wildlife Services, Washington, D.C., unpubl. rep, 1971). A $16,500 increase in preventive aerial hunting in 1995 was credited with a reduction in coyote predation from 2,234 head of sheep killed on the Caribou National Forest in 1994 to 1,121 head in 1995 (ADC, Weekly Activity Report, March 15, 1996). According to estimates from Idaho National Agriculture Statistics Service, if the entire reduction in losses was attributed to aerial hunting, each dollar spent in aerial hunting saved $5.40 in livestock. However, all of this reduction cannot be attributed to aerial hunting, because there was an average 28% statewide reduction in sheep and lamb losses to coyote predation in Idaho, Utah, and Wyoming during the same period (USDA 1996a,b,c).

It is unlikely that preventive aerial hunting will be used in the absence of corrective summer control (Berryman 1973, Wade 1978). If aerial hunting is effective, it may result in a reduction in the need for corrective summer predation management (henceforth referred to as SPM). Aerial hunting also may reduce the risk to nontarget species because, during aerial hunting, the animal is identified as a coyote before it is shot (USDI 1978, USDA 1994). If aerial hunting reduces the need for summer control, there should be a decrease in the use of less-selective corrective control techniques (traps, snares, and M-44's), and interactions between ADC programs and recreational activities may be minimized. In general, ADC specialists respond to predation problems by employing 1 or 2 management techniques, and try additional techniques if it becomes apparent the initial methods cannot resolve the problem. Therefore, it may be possible to use the number of techniques employed for predation management as an indicator of the severity of the predation problem. I predicted that if aerial hunting was effective, fewer techniques should be used in areas subjected to aerial hunting than in areas without aerial hunting.

Of the 3 requirements described by Wagner (1988) for the population control hypothesis, the most controversy surrounds the ability of aerial hunting to significantly reduce local coyote populations, and the duration of any population reduction. As mentioned earlier, aerial hunting is an efficient (coyotes killed/unit effort) means of removing coyotes and appears to have the potential to significantly reduce local coyote populations. If aerial hunting does significantly reduce local coyote populations, there should be a negative correlation between the intensity of coyote removal (coyotes killed/km^2) and sheep losses to coyote predation, and/or the need for corrective predation management.

Knowlton (1972) recommended scheduling removals so they occur after the main coyote dispersal period and just prior to whelping. Coyote removals at this time improve the probability that coyote deaths from aerial hunting will be additive and not compensatory to dispersal mortality, and may remove some of the offspring that would have been born during the subsequent whelping season. Peak seasonal dispersal periods have been defined as August-January in Montana (Pyrah 1984), November-January in Texas (Knowlton 1972), and August-December in California (Shivik et al. 1996). In a study by Davison (1980) of northern Utah/southern Idaho coyote populations, 57% of the emigration observed in a highly exploited coyote population occurred during December-January, and 28% occurred from September-October. In the lightly exploited population, 54% of the emigration observed occurred from September-November, and 31% was observed from late February through early April. Therefore, given a January-March window for preventive aerial hunting, coyote removals in March would appear to have the best probability of being additive mortality.

If preventive aerial hunting is effective because it reduces local coyote populations (population control hypothesis), the reduction must last the 3-6 months before sheep arrive and for at least a portion of the summer grazing season (mid-June-September; Wade 1978, Wagner 1988). As mentioned earlier, preventive aerial hunting occurs from January-March, but the sheep are not placed in these areas until mid June-July (Wade 1976). Given that areas with aerial hunting often are relatively small and surrounded by areas without aerial control (potential source populations), immigration may negate reductions in coyote density by the time the sheep arrive on the summer allotments. For example, in an unpublished study by E. M. Gese (USDA Predator Ecology Center, pers. commun.), a Colorado coyote population in a 340 km^2 area was reduced approximately 50% by January aerial hunting (based on scent station indices and density estimates). Territory size, pack size, and density estimates had returned to pretreatment levels within 4-5 months.

The timing of aerial hunting may be especially important for the population control hypothesis. Using the 4-5 month population recovery period from the study by E. M. Gese (USDA Predator Ecology Center, pers. commun.) coyote populations in areas receiving January aerial hunting would recover by May-June. Reductions occurring in March would have the best probability of lasting until late September when the sheep leave the summer grazing areas. Using this prediction and the prediction mentioned above that aerial hunting mortality caused later in the season was most likely to be additive, I predicted a negative correlation between the Julian date of aerial hunting and sheep losses to coyote predation.

As used in this study, preventive aerial hunting might disrupt breeding because it is conducted from January-March, a time period that includes the January-February coyote breeding season estimated by Knudsen (1976) for Utah coyotes (breeding pair theory). Even if the last date for conception is extended to the end of March, the duration of population disruption required for the breeding pair theory would be 0-3 months instead of 3-6 months for the population control hypothesis. Because of this difference in the necessary duration of effect, a correlation between the timing of aerial hunting and sheep losses can occur but is not required by the breeding pair hypothesis. Coyote densities may reach precontrol levels by the time sheep arrive on the allotment, but sheep losses may be reduced because there are fewer coyotes with pups in the population.

It is unclear whether this hypothesis requires a relationship between the intensity of coyote removal and sheep losses to coyote predation. The answer may depend on which coyotes are vulnerable to aerial hunting. If, as suggested by Windberg and Knowlton (1990), juvenile coyotes are considerably more vulnerable to aerial hunting than adults, substantially more coyotes will need to be removed to have an impact on the number of breeding pairs and the more likely there will be a relationship between hunting intensity and losses to coyote predation. For best results, the majority of depredating coyotes removed during SPM from areas without aerial hunting should be reproductively active.

The problem coyote hypothesis predicts that some preventive control techniques can be used to capture coyotes that are less vulnerable to corrective control techniques. The use of preventive winter aerial hunting adds another technique to the list for managers protecting sheep on summer grazing areas of the Intermountain West. Aerial hunting is generally not available for corrective predation management because plant foliage prohibits efficient location of coyotes. To test the hypothesis, I assumed that older coyotes were more likely to have learned to avoid corrective management techniques. Therefore, if aerial hunting removes the older, more experienced coyotes, then the average age of adult coyotes captured with aerial hunting should be higher than for coyotes captured during SPM in areas with aerial hunting. The problem coyote hypothesis can have, but does not require a relationship between the timing of aerial hunting and sheep losses to coyote predation. Most new territory holders are likely to have been nonterritorial juveniles and yearlings (Knowlton 1972, Camenzind 1978, Gese et al. 1988); therefore, the average age of coyotes removed during SPM from areas with aerial hunting would be lower than for areas without aerial hunting. As with the breeding pair hypothesis, the relationship between hunting intensity and sheep losses to coyote predation will depend on which coyotes are vulnerable to aerial hunting.

This study also tested assessed wether sheep losses to coyote predation were compensatory or additive by comparing sheep losses to all causes and sheep losses to coyote predation between areas with and without aerial hunting. If preventive aerial hunting successfully reduced coyote predation but coyote predation is a compensatory form of mortality, areas with aerial hunting should have lower losses to coyote predation but no difference in number of sheep lost to all causes. Conversely, if coyote predation is an additive form of mortality, then areas with aerial hunting should have lower sheep losses to coyote predation and a lower number of sheep lost to all causes.

An alternative method for addressing problems caused by wildlife is to manage human perceptions and tolerance of the damage (Olsen 1991, McIvor and Conover 1994, Musgrave and Stein 1993, USDA 1994). Financial compensation for damages caused by wildlife is one option for achieving this goal. However, opinions are mixed as to the value of compensation as a management tool. Compensation programs eliminate the risk of direct injury to humans and wildlife from damage management tools like traps and pesticides (Olsen 1991). However, in a survey by McIvor and Conover (1994), both farmers and nonfarmers in northern Utah and southern Idaho had a higher approval of hunting than of compensation programs as solutions to damage caused by sandhill cranes (Grus canadensis). Sixty-nine percent of farmers and 50% of nonfarmers approved of hunting, while only 32% of farmers and 23% of nonfarmers approved of compensation programs. Compensation does not stop the damage and may not be appropriate in situations where wildlife causes a risk to human health and safety (USDA 1994). Failure to address problems attributable to high wildlife densities and continued population growth may result in harm to the problem species, local vegetation, and other associated wildlife as well as increased damage (USDA 1994).

Despite differences in opinions on the technique and expenses as high as $2,350,000 in a year with severe problems in 1 state (M. Whitt, L. W. Adams, and J. P. Linduska. Young hunter programs and large mammal crop depredation control, Nat. Res. Manage. Prog., Univ. Maryland, College Park, 1993), little information is available on the use of compensation in the U.S. and Canada. To address this issue, I sent surveys to the wildlife management agencies in the U.S. and Canada to determine the extent and nature of existing compensation programs.

Modern wildlife damage management programs are required to provide effective and socially acceptable damage control options (USDA 1978, Schmidt 1989, USDA 1994). This requires a sophisticated understanding of the management techniques available and associated social issues that goes beyond the impact of aerial hunting on sheep losses to predation (Arthur et al. 1977, Gum and Martin 1979). This study was designed to provide some of the information necessary for more informed management decisions by examining the impact of aerial hunting on sheep losses to predation, the total number of coyotes killed, the need for corrective summer predation management, and the risk to nontarget species. It also evaluates the impact of aerial hunting on coyote populations by examining data on the age and reproductive status of coyotes removed through aerial hunting. Financial compensation programs for wildlife damage in North America are examined as an alternative to traditional wildlife damage management procedures that focus on managing the wildlife instead of altering human behavior and perceptions of the damage.

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CHAPTER 2

IMPACT OF PREVENTIVE WINTER AERIAL COYOTE HUNTING ON SHEEP LOSSES TO COYOTE PREDATION IN MOUNTAIN GRAZING ALLOTMENTS[1]

Abstract: Aerial hunting is commonly used by agriculture agencies in the Intermountain West to reduce coyote (Canis latrans) predation on sheep (Ovis aries). We assessed the impact of winter aerial coyote hunting on sheep losses to coyotes and the need for predation management (hours of work, device nights) 3-6 months later during the ensuing summer grazing season, by comparing sheep loss to coyote predation between paired grazing allotments with (treated allotments) and without (untreated allotments) winter aerial hunting from helicopters. Confirmed lamb losses to coyote predation in treated allotments ($\bar{x}$ = 2.7, SE = 0.6) were significantly less than in untreated allotments ($\bar{x}$ = 7.3, SE = 1.6, P = 0.01), as were estimated lamb losses to coyotes (treated $\bar{x}$ = 11.8, SE = 6.2; untreated $\bar{x}$ = 35.2, SE = 8.1, P = 0.02). Hours required for summer coyote control also were significantly less (P = 0.01) in treated allotments ($\bar{x}$ = 37.3, SE = 8.5) than in untreated allotments ($\bar{x}$ = 57.2, SE = 11.3). Winter aerial hunting increased the mean number of coyotes killed annually per allotment from 2.0 (SE = 1.0) to 5.7 (SE = 1.1, P = 0.04). It did not impact the number of coyotes removed during summer coyote control (P = 0.52). Based on 1995 values for lambs and labor, winter aerial hunting of coyotes had a benefit:cost ratio of 2.6:1.

Coyote (Canis latrans) predation is a serious problem for livestock producers in the western U.S. In 1994, an estimated $17.7 million in sheep were lost to predators in the U.S., with the majority of losses attributed to coyotes (USDA 1995). In Utah, Idaho, and Wyoming, 34% of all producer-reported sheep and lamb losses were to coyote predation, amounting to $4.8 million in losses during 1995 (USDA 1996a,b,c). Aerial hunting is an efficient

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(coyotes/unit time) means of removing coyotes, especially in areas with limited access or rough terrain (J. H. Berryman, USDI Wildlife Services, Washington, D.C., unpubl. rep.; USDI 1973a,b; Sterner and Schumake 1978; Wade 1978). However, efficiency in removing coyotes guarantees neither a reduction in coyote abundance nor depredations (Connolly and Longhurst 1975, Wagner 1988). There is not much information available assessing the effectiveness of aerial hunting in reducing livestock losses or the role it plays in predation management programs.

During aerial hunting, coyotes are shot by hunters from aircraft. For best results, coyotes are located by following tracks in fresh snow, or by coordinating efforts with a separate hunter on the ground who elicits vocal responses from coyotes with the use of sirens and coyote calls, and then radios the information to the aircraft. Fixed-wing planes are usually used for areas with flat or gently rolling terrain, while helicopters are preferred for steep mountainous terrain in areas like the summer grazing pastures of the Intermountain West (Wade 1976, USDI 1978).

Aerial hunting can be used as a corrective or a preventive management technique. As a corrective technique, coyotes are killed after losses occur, while as a preventive technique, coyotes are removed from areas before sheep arrive (Sterner and Shumake 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 (USDI 1978, Wade 1978). In 1988, 2,768 coyotes were shot from helicopters in Idaho, Nevada, Utah, and Wyoming, primarily during preventive aerial hunting programs (USDA 1994). In federal fiscal year 1995, 391 coyotes were killed by the ADC program using helicopters in National Forests in Utah during preventive aerial hunting programs on summer grazing areas (Utah ADC, unpub. data). In the Intermountain West, aerial hunting to protect summer grazing areas usually occurs from January-March, but sheep are not placed in these areas until June-July. Critics of this method are concerned that hunting conducted 3-6 months before the sheep arrive may not reduce coyote predation on sheep or the need for corrective summer predation management (henceforth referred to as SPM).

Few studies have evaluated the impact of preventive aerial hunting programs. In Texas, 40 hours of combined corrective and preventive aerial hunting conducted from April 24-April 30 did not reduce sheep losses to coyote predation (T. E. Anderson, M. Caroline, and J. L. Beavers, USDI Wildl. Serv., An evaluation of aerial hunting as a means of protecting sheep and goats from coyote and bobcat predation in Uvalde and Kinney Counties, Texas, Albuquerque, NM, 1974). However, they hypothesized that foliage prevented efficient predator location and suggested improved results might be obtained if control was conducted in winter when foliage was reduced.

In a study conducted by C.J. Packham (USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973), aerial hunting was compared to ground control techniques when both were used for corrective and preventive management. Preventive aerial hunting was conducted 1-12 weeks before lambing but preventive ground control was conducted during the fall prior to the lambing season. Both areas received corrective control as needed. A combined 39-hr (165%) increase in aerial hunting and 3.5-day (2.3%) increase in trapping time resulted in lamb losses that were 34% of the prior year's losses, but the 27-day (84%) increase in trapping effort in similar areas without aerial hunting resulted in lamb losses 131% higher than in the prior year. The study did have some replication (4 treated areas, 2 control areas), but the differences in the time between preventive control and lambing and in the magnitude of increase in control effort (165% vs 84%) make comparisons difficult. Additionally, the time between treatment and sheep arrival in the Packham study in this study (1-12 weeks) was less than commonly found between preventive winter aerial hunting and sheep arrival on summer grazing allotments of the Intermountain West (3-6 months).

Some information is available on the use of preventive aerial hunting to improve pronghorn antelope (Antilocapra americana) and deer (Odocoileus spp.) fawn survival. Smith et al. (1986) evaluated a program using helicopters to remove coyotes from a pronghorn range just prior to the fawning season. The 0.57 fawn:doe ratio during 3 years with aerial hunting was higher than the average of 0.31 during years when only trapping was used. Smith et al. (1986) modeled the benefit:cost ratio of various coyote hunting schedules and suggested a 1.9:1 ratio for control used every other year. Other studies support findings that preventive predator removal can enhance pronghorn populations (Arrington and Edwards 1951, Udy 1953). Aerial removal of coyotes increased deer (O. virginianus) productivity in Oklahoma (Stout 1982) and south Texas (Guthery and Beasom 1977). In general, results of programs using coyote removal to protect deer have been highly variable (Connolly 1981). The success of aerial hunting depends on herd size relative to carrying capacity, coyote population size relative to the number of deer, availability of alternate prey, and the impact of the control program on the predator population (Connolly 1981, Hobson 1990).

Preventive aerial hunting usually does not stop all coyote predation and additional efforts are needed during the grazing season. However, presumably the amount of SPM required may be lower in areas with aerial hunting than in areas without aerial hunting. This is especially true for U.S. Forest Service lands that may require confirmation of predator kills before SPM can occur. Because techniques used for SPM include traps, snares, and M-44's, which have the potential to injure or kill nontarget species (USDI 1978, USDA 1994), reducing SPM should also reduce risks to nontarget species.

Modern wildlife damage management programs should provide effective and socially acceptable damage management options (USDI 1978, Schmidt 1989, USDA 1994). This requires a sophisticated understanding of the management techniques available, their impact on target species, and their risks to nontarget species (Gum and Martin 1979, Arthur et al. 1977). Information is also needed on the impact of each technique on the need for using other techniques, and the costs and benefits of the supplemental techniques. This study focused on the use of aerial hunting as a preventive control technique, in part, because of the controversy surrounding the timing of aerial hunting in relation to summer grazing seasons (Connolly and Longhurst 1975, Wagner 1988). It was designed to provide information for management decisions by examining the impact of aerial coyote hunting on sheep losses to predation, number of coyotes killed, subsequent need for SPM, and the potential risk to nontarget species.

METHODS

The field experiment was conducted from December 1992 through September 1995, and included 3 winter hunting periods (January-March) and the subsequent summer grazing seasons. We collected data on sheep bands using 41 summer grazing allotments. Five grazing areas were on privately owned pastures in Iron County, Utah. The remaining areas were located in USFS lands in Utah and Idaho: the Teasdale (2 allotments) and Cedar (5) districts of the Dixie National Forest; the Price (5), Ferron (6), and SanPete (6) districts of the Manti-LaSal National Forest; the Loa (1) and Richfield (2) districts of the Fishlake National Forest; the Heber (2) district of the Uinta National Forest; the Ogden (2) and Logan (2) districts of the Wasatch-Cache National Forest, the Soda Springs (2) and Pocatello (1) districts of the Caribou National Forest, and the Burley (3) district of the Sawtooth National Forest. Sheep bands grazed these areas from about mid-June through the end of September.

Budget constraints prevented us from placing aerial hunting in specific locations. Therefore, each year, allotments with aerial hunting (treatments) were paired with other allotments (untreated) where aerial hunting should have occurred but did not for logistical reasons (limited funds, unavailability of aircraft, and/or weather conditions unsuited to aerial hunting). Pairings were first based on similarities in terrain: proportion of area suitable for aerial hunting: proportion of rough terrain and understory vegitation that can reduce the effectiveness of some damage management practices like livestock guarding dogs. We also made certain lambs in both areas were of similar age because the size and age of lambs can affect their vulnerability to predators. Last, we paired allotments based on the use or absence of livestock guarding dogs. We interviewed all woolgrowers using the selected allotments. If a woolgrower was reluctant to participate in the program, was unwilling to provide sheep counts, or combined the sheep band with neighboring bands with differing treatments, he or she was not included in the study. To minimize the risk of coyotes moving between untreated and treatment allotments, a minimum distance of 6.5 km and optimal distance of 13 km between sites were chosen. This 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). Shorter distances were accepted if significant topographic barriers to coyote movements (e.g., large rivers, cliffs) were present between sites.

Twenty-one pairs of allotments (8 in 1993, 6 in 1994, 7 in 1995) were used in the study. In 2 instances, we knew sheep in adjacent areas with the same treatment would be mixed prior to the end of the grazing season. Data were collected from both areas and pooled to make half of a study pair (pooled allotments). The area for the 2 pooled allotments ($\bar{x}$ = 37 km^2) was similar to the mean area of allotments with 1 sheep band ($\bar{x}$ = 39 km^2).

Numbers of ewes and lambs entering each study allotment were obtained from the livestock producers or from videotaping sheep as they moved past a narrow, fixed observation point en route to the study area. In some instances, the most recent producer count of ewes and lambs was several weeks prior to arrival in the study area and it was not possible to gather the sheep for videotaping. To avoid including losses from this prestudy period in our evaluation, we first 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. Total sheep loss prior to the study (L_p) was then estimated 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). Calendars also provided space for recording the number of coyotes killed on each study site by woolgrowers and shepherds. We checked with herders 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) using criteria described by Wade and Bowns (1985). Confirmed loss is the number of dead lambs ADC field specialists and study personnel examined and certified as being killed by coyotes. Livestock producers are only able to locate a portion of the total number of sheep that die and the number of confirmed cases of coyote predation probably underestimates actual loss (Taylor et al. 1979, Scrivner et al. 1985). Estimated loss was obtained using the following equation to estimate the total number of ewes (L_{ee}) or lambs (L_{el}) likely to be killed by coyote predation during the study period

$$L_{ee} \text{ or } L_{el} = C_{cs} + (C_{cs}/L_{ks})L_{us},$$

where C_{cs} is the number of confirmed coyote kills (lambs or ewes), L_{ks} is the known number of lamb or ewe deaths to all causes, and L_{us} is the number of sheep unaccounted for at the end of the study period. Although there is margin for error in any estimate of loss, we believe the error in our estimates is likely to underestimate lamb losses to coyote predation. In many instances there was insufficient evidence to determine cause of death and some losses to coyote predation were probably classified as losses to other causes when calculating estimated losses to coyote predation.

To quantify potential risk to nontarget species from SPM, we multiplied the number of foothold traps, neck snares, and M-44's (a device spraying sodium cyanide powder into the mouth of coyotes pulling on a plug coated with a coyote-attracting lure; USDA 1994) in use by the number of nights the tools were used on an allotment (henceforth called the number of device nights). Calling-and-shooting and denning were not included in this measure because the animal is usually identified as a coyote before it is killed. Records of the use of traps, snares, and M-44's; number of coyotes killed during summer work; number of coyotes killed from aircraft; hours of SPM; hours of aerial hunting; and the number of different damage management techniques (tools) used during summer control were kept for each allotment by the ADC field specialists.

Comparison During the Pretreatment Period

Our data analysis for the treatment period assumed that there were no differences between treated and untreated allotments in the absence of aerial hunting. To test this assumption, we were able to obtain pretreatment data (years when neither member of a pair received aerial hunting) from Utah ADC records for 11 of 21 pairs of allotments during 1990-1994. For each study pair with pretreatment data, we randomly selected a year when neither half of the pair 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 ADC personnel), and the number of lambs lost to all causes. Data on hours of work (SPM) from the historical data set were not analyzed as it was impossible to separate time spent on bear and lion predation from time spent on coyote predation.

Data from the pretreatment period were analyzed to assess whether differences existed between those allotments that were to become untreated allotments and those that were to receive aerial hunting. This analysis used the same statistical methods employed for data from the treatment period.

Comparison During the Treatment Period

We used the Wilcoxson matched-pairs signed-rank test (Seigel 1956) to evaluate differences between treated and untreated allotments. Differences were considered significant if $\underline{P} \leq 0.05$. Data on ewe losses to predation were not analyzed, because coyotes rarely killed ewes (8 confirmed ewe losses for the entire experiment), and confirmed ewe kills were located on < 30% of the allotments

RESULTS

Comparison During the Pretreatment Period

During the pretreatment period, confirmed lamb loss to coyote predation, and lamb loss to all causes did not differ between those allotments that later became untreated areas and those that received aerial hunting ($\underline{P} \geq 0.22$; Table 2.1). There were no significant differences in the number of coyotes killed during SPM ($\underline{P} = 0.72$).

Comparison During the Treatment Period

Aerial-hunted allotments received an average of 2.1 hrs of aerial hunting (SE = 0.4) with an average take of 4.9 coyotes (SE = 1.8) or 2.3 coyotes/hour. This equated to an average of 0.1 coyotes/km^2 (Table 2.2). Aerial-hunted allotments received significantly fewer hours of SPM than untreated sites, and had significantly fewer confirmed and estimated lamb losses to coyotes (Table 2.2). Aerial hunting also resulted in a reduction in the number of device nights that approached significance at $\underline{P} = 0.10$ (Table 2.2). Aerial hunting increased the total number of coyotes removed from an area ($\underline{P} \leq 0.05$) but did not reduce the number of coyotes removed during SPM ($\underline{P} \geq 0.05$).

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 on the allotment. Our finding that the percent of lambs lost to coyote predation was reduced from 2.8% in untreated allotments to 0.9% in treatment allotments is comparable to the reduction in reported losses of 1.9% to 0.6% in the study conducted by C.J. Packham (USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973). 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 study conducted by C.J. Packham (USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973).

When sheep and lambs are killed by coyotes in the summer, ADC responds by devoting time and materials to removing offending predators. We found that aerial hunting in winter reduced the amount of SPM, both in the hours of summer work and the number of device nights. However, there was no difference in the number of coyotes killed during SPM. The lack of significant difference in the number of coyotes killed during SPM is surprising given that there were significantly fewer hours of SPM required on areas with aerial hunting. This may indicate that less time was required to capture problem coyotes in areas that received aerial hunting. Data suggest that a coyote's ability to avoid some corrective control tools may increase with coyote age (experience) and social status (territoriality) (Andelt et al. 1985, Windberg and Knowlton 1990). If true, then the average age for coyotes removed through corrective control should be lower in areas with aerial hunting programs than in area without aerial hunting. This hypothesis is tested in a later chapter of this dissertation. Alternatively, the lack of significant 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. This may be especially true in cases when multiple traps, snares, or M-44's are set, because the "target" coyote(s) may be caught but the remaining devices can still capture coyotes.

The potential reduction in device nights as a result of aerial hunting represents a decrease in risk to nontarget species, because species other than coyotes can fall prey to traps, snares, and M-44's. In contrast, with aerial hunting, the animal must be identified before it can be shot. The drop in SPM hours and device nights caused by aerial hunting has additional value in areas that receive high recreational use by reducing the amount of contact between recreationists and damage management operations, and the associated potential for conflicts. 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 hours, ADC field specialists may have avoided using traps in areas with limited access.

Despite the increase in SPM in untreated allotments over treatment allotments, lamb losses were still significantly higher in untreated allotments. This indicates that the levels of SPM employed in this study were not an adequate substitute for aerial hunting. Similar results were obtained in a study by C.J. Packham (USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973) in which sites with a 27-day (85%) increase in trapping effort had losses higher than the prior year, but sites with a 39-hour (165%) increase in aerial hunting time had losses lower than the prior year. This may result because SPM techniques were used after coyote predation on livestock has begun and did not prevent the earlier losses, or because aerial hunting was a better means of removing coyotes with a greater likelihood of killing sheep. An alternative explanation is that the ADC specialists believe that aerial hunting is an effective tool and may not check with shepherds in aerially hunted areas as often as in untreated areas. However, in most instances, this seems unlikely as ADC specialists generally only check with shepherds after the shepherd or woolgrower has requested assistance.

As used in our study, aerial hunting with helicopters was a cost- and time-efficient means of removing coyotes. In Utah, the cost of aerial hunting including helicopter rental, wages for the pilot and ADC hunter, ammunition, and incidentals was estimated at $425/hour, and the average cost to keep an ADC field specialist supplied and in the field for a year (1852 hours of work) was approximately $50,000 ($27/hour, Mike Bodenchuk, Utah ADC pers. commun.). Using data for the average allotment in our study, aerial hunting removed 2.3 coyotes/hour at a cost of $185/coyote while corrective control removed 0.03 coyotes/hour (data from allotments with and without aerial hunting combined) at a cost of $805/coyote (Table 1.1).

Although aerial hunting was an efficient means of removing coyotes, their removal does not always guarantee a reduction in losses (Connolly and Longhurst 1975, Wagner 1988). Our results show that 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 hours ($893) of aerial hunting per allotment resulted in an average difference of 19.9 hours ($537) of SPM. Using our estimates of lamb losses to coyote predation, aerial hunting resulted in an average savings of 23.4 lambs per allotment over treated allotments. At a 1995 average price of $75.86 for a 45 kg lamb (USDA 1996d), this would equal a savings of $1,775 per allotment. Hence $2,131 of benefits resulted from $893 in expenses, yielding a 2.6:1 benefit:cost ratio.

Our calculations are conservative in that we did not include cost of travel time to the allotments. The cost of SPM may be higher for large areas or areas with limited vehicle access. With current budget restrictions, ADC personnel are often unable to promptly address all requests for ADC assistance, and time saved on 1 allotment with aerial hunting can be spent assisting other producers.

Our data provide evidence supporting the use of preventive winter aerial coyote hunting as a depredation management technique, but caution should be used when extrapolating the data to other situations. This study was conducted under a relatively narrow set of environmental conditions. Changes in terrain, in coyote density, and in the intensity or timing of aerial hunting may affect the results. Although, in general, aerial hunting reduced sheep losses to coyote predation, this was not true for all allotments. Without an understanding of the mechanisms that make aerial hunting effective, we cannot fully use the potential of this technique. For example, the preventive aerial hunting used in our study was conducted during the breeding season. If preventive aerial hunting was successful because it interrupted the formation of coyote pairs that could successfully breed, then hunting during other seasons may not be effective. Alternatively, if this technique was effective because it reduced local coyote populations, then we will need an understanding of the relationship between hunting intensity and expected reductions in sheep losses before managers can predict the appropriateness of this technique for a given location.

MANAGEMENT IMPLICATIONS

Preventive aerial hunting from helicopters in winter can be an effective means of reducing sheep losses to coyote predation on summer grazing allotments 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 M44's. 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 grazing areas, 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 because 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. In areas with intensive summer recreation, aerial hunting may be an especially appropriate tool as it also reduces risk to nontarget animals and minimizes contact between damage management operations and recreationists. Alternatively, stakeholder concerns over the number of coyotes killed and a desire to focus on offending individuals may make aerial hunting less desirable.

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Table 2.1. Comparison of 11 pairs of grazing allotments during the pretreatment period (1990-1994). During the subsequent treatment period, half the allotments received aerial hunting (treated allotments) and the others did not (untreated allotments).

	Treated		Untreated		
	$\bar{x}$	SE	$\bar{x}$	SE	P[a]
Pretreatment period					
Confirmed lamb losses to coyotes	2.9	1.1	5.4	3.9	0.68
Ewes lost to all causes	27.8	11.2	38.1	18	0.4
Lambs lost to all causes	69.8	19.3	100	14.4	0.22
Coyotes killed during summer work	1.4	0.7	1	0.3	0.72

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

Table 2.2. Comparison of 21 pairs of Utah and Idaho summer grazing allotments during a 1993-1995 treatment period when 1 allotment in each pair received aerial hunting (treatment allotments) and the other did not (untreated allotments). Aerial hunting occurred from 1 January - 30 March and summer work occurred from 15 June - 30 September.

	Treated allotments		Untreated allotments			
	$\bar{x}$	SE	$\bar{x}$	SE	Z [a]	P [a]
Allotment size (km^2)	45.2	14.1	30.9	4.6	-0.26	0.79
No. of ewes present	1098	88.3	1002	71.6	-0.89	0.37
No. of lambs present	1226	148.8	1236	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
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	1	-0.65	0.52
Total coyotes killed	5.7	1.1	2	1	-3.2	0
Confirmed lambs killed by coyotes	2.7	0.6	7.3	1.6	-2.79	0
Estimated lambs killed by coyotes	11.8	6.2	35.2	8.1	-2.4	0
Lambs lost to all causes	52.4	14.3	94.4	17.8	-0.86	0.39

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

[b] Number of traps, snares, and M-44s used X number of nights they were in use in an allotment.

CHAPTER 3

IMPACT OF SNOWFALL ON THE UTAH PREVENTIVE AERIAL HUNTING PROGRAM[2]

Aerial hunting is one of the tools 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). In research conducted by Wagner (1997), areas with preventive aerial hunting had lower confirmed and estimated lamb losses to coyote predation, and required significantly fewer hours of additional corrective predation management than areas without aerial hunting. Aerial hunting is perceived to be especially valuable for large areas and areas with rough terrain and limited access (USDI 1973a,b; Sterner and Schumake 1978; Wade 1978). However, use of this technique is limited by many variables, including funding, helicopter availability, and environmental requirements for safe and effective hunting (Wade 1976, USDI 1978).

During aerial hunting, coyotes are shot by hunters from aircraft. Due to their greater maneuverability, helicopters are preferred for aerial hunting in the steep, mountainous terrain used for summer grazing in the Intermountain West (Wade 1976, USDI 1978). Aerial hunting is generally restricted to winter when cold, dense air is optimal for safe flying conditions, and plant foliage is at a minimum. Snow cover improves hunting efficiency because coyotes and their tracks are more conspicuous on a white background (C.J. Packham, USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973; Wade 1976). The efficiency of aerial hunting can also be improved by coordinating the efforts of the team in the aircraft with ground personnel using sirens and calls to help locate coyotes (Wade 1976). However, in many areas of the Intermountain West, access from the ground is unavailable or impractical and tracking in snow becomes especially important. Consequently, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage

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[2]Coauthored by Kimberly K. Wagner and Michael R. Conover

Control (ADC) personnel in the Intermountain West generally prefer to hunt within 48 hours of a snowfall with low winds between the period of snowfall and hunting to facilitate tracking (J. Winnat, Utah ADC, pers. commun.).

Because of the importance of snow in aerial hunting programs of the Intermountain West (C.J. Packham, USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973), we examined the impact of low snowfall on aerial hunting as used by ADC personnel in Utah National Forests. Low snowfall can impact the hunting programs by reducing the extent (area treated, hours of hunting), intensity (hours/km^2, coyotes killed/km^2), and/or efficiency (coyotes killed/hour) of aerial hunting. If aerial hunting teams always select optimal hunting conditions, then there may be a decrease in the extent of aerial hunting but no decrease in the efficiency of aerial hunting. In contrast, if hunting teams accept less desirable hunting conditions during years with low snowfall there might not be a decline in the extent of aerial hunting but there would be a decline in the intensity and/or efficiency of aerial hunting.

METHODS

To evaluate the impact of snowfall on aerial hunting programs, we obtained Utah ADC records for the Manti-La Sal and Wasatch National Forest summer grazing areas from 1990-1995. The study included sheep grazing areas in 3 regions: (1) the Ferron, Price, Manti, and Sanpete ranger districts of the Manti-La Sal National Forest (Manti); (2) the Bear River and Mountain View ranger districts of the Wasatch National Forest located on the north slopes of the Uinta mountain range (North Slope); and (3) the Logan and Ogden ranger districts of the Wasatch National Forest located east and south of Logan, Utah (Logan). Study areas were selected based on consistent woolgrower financial support of winter aerial hunting programs and the absence of legal bans on winter predator control from 1990-1995.

Data on annual snowfall and average snowfall levels were obtained from the Utah Climate Center in Logan, Utah, and from Ashcroft et al. (1992). We arbitrarily selected <75%

normal snowfall as the definition of a low snowfall year. Snowfall data were examined to identify winters from 1990-1995 with <75% average snowfall for the period from January - March, and the most recent 3 years with average or above average snowfall for each forest unit.

To assess the impact of low snowfall on the extent, intensity, and efficiency of winter aerial hunting from helicopters, we obtained data on the area treated, hours of hunting, and number of coyotes killed during aerial hunting for each forest region during the high and low snowfall years from Utah ADC records. We compared the measures of extent, intensity, and efficiency of aerial hunting between high and low snowfall years using an analysis of variance for studies with unequal sample size (Steele and Torrie 1980).

RESULTS

Low snowfall conditions occurred in the North Slope and Logan units during 1991 and 1992, and in the Manti unit in 1992. Average to above average snowfall occurred in 1990, 1993, and 1995 for all 3 study areas. During the remaining periods, snowfall was below average but above the 75% normal criterion established for use as a low-snowfall year. Hence, data from these period were not used in the data analysis.

Years with low snowfall had significant reductions in 2 of 3 measures of the extent of aerial hunting (area hunted $\underline{P} = 0.04$ and hours of aerial hunting $\underline{P} = 0.02$; Table 3.1). Although not significant ($\underline{P} = 0.09$), the number of coyotes killed in years with low snowfall ($\underline{\bar{x}} = 15$, SE = 7) was substantially lower than in years with normal or high snowfall ($\underline{\bar{x}} = 35$, SE = 8). Hunting intensity and hunting efficiency did not significantly differ between years with and without low snowfall (Table 3.1) The only times when aerial hunting did not occur in a forest unit (Logan 1991, North Slope 1991) were during years with low snowfall.

DISCUSSION AND IMPLICATIONS

During years with low snowfall there was a significant reduction in the time spent aerial hunting and in the area covered by aerial hunting. However, the areas that received aerial hunting did not differ in hunting intensity or efficiency (coyotes killed/km^2, coyotes killed/hour). The use of aerial hunting in states with little or no snow suggests that it is possible to hunt without fresh snow. Even in Utah, aerial hunting from fixed-wing aircraft is used during periods of low or no snow for corrective and preventive control in lower elevations with greater access for ground crews. However, the consistency in the level of efficiency and the absence of hunting from helicopters in some years with low snowfall indicates that ADC field specialists are choosing to reserve hunting resources (money for aerial hunting from helicopters) for periods when conditions for hunting are optimal, even at the risk of having no aerial hunting. This is contrary to critics' claims that personnel use any opportunity available to kill coyotes and respond to pressures from ranching interests that often want to see evidence of effort to remove coyotes. The lack of reduction in coyotes killed/hour and coyotes killed/km^2 may also be attributable to the fact that ADC personnel rely upon fresh snow and not overall snow depth to facilitate tracking and locating coyotes from aircraft. Therefore, the number of snowstorms may be a more critical factor.

The decline in the area receiving aerial hunting during low snowfall years was probably the result of an interaction between fewer snowfall events and difficulties scheduling helicopters and not just low snowfall per se. Helicopter scheduling was an ongoing problem for Utah ADC with only 5 pilots in the state authorized to fly helicopters for aerial hunting. Utah ADC must compete with other agencies for helicopter time. Consequentially, even with appropriate weather conditions, hunting may not occur because helicopters are not available. Managers wishing to counteract the impact of low snowfall will have to find means of improving helicopter availability by establishing contracts with more pilots or by providing incentives for pilots to give their program higher priority when hunting conditions are suitable.

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Table 3.1. Winter aerial coyote hunting in Utah[a] during years with low snowfall (<75% of normal from January-March) or above average snowfall.

	Normal to above-normal snowfall[a]		Low snowfall[b]		
	$\bar{x}$	SD	$\bar{x}$	SD	P[c]
Extent of aerial hunting/forest unit					
Area hunted (km^2)	488	137	201	101	0.04
Hours hunting	20.1	5.1	6.5	2.9	0.02
Total coyotes killed	35	8	15	7	0.09
Intensity of aerial hunting					
Hunting intensity (hrs/km^2)	0.04	0.01	0.03	0.01	0.07
Kill intensity (coyotes killed/km^2)	0.09	0.02	0.07	0.03	0.44
Efficiency of aerial hunting					
Coyotes killed/hour	2.1	0.4	2.0	0.6	0.97

[a] Data were from 1990, 1993, 1995 for all Manti, Logan and North Slope study areas.

[b] Data were from 1992 for Manti study area and 1991,1992 for the North Slope and Logan study areas.

[c] Based on results of analysis of variance.

CHAPTER 4

THE IMPACT OF PREVENTIVE PREDATION MANAGEMENT ON COYOTE POPULATIONS: A TEST OF HYPOTHESIS[3]

Abstract: Preventive aerial hunting can be an effective means of reducing coyote predation on sheep, but it is also expensive and controversial. Hence, we need an understanding of the mechanisms that make aerial hunting an effective management tool. We used data from field studies and U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control program (ADC) records to address these issues. There were no consistent correlations between any measure of the extent or intensity of aerial hunting and sheep losses to predation or the need for corrective summer predation management (SPM). This lack of correlation may have been attributable to helicopter crews spending more time hunting in areas with a history of high predation problems than in areas with fewer predation problems. Aerial hunting efforts in these areas may reduce losses, but the new level of loss may still be higher than that for areas with inherently lower losses. Timing of aerial hunting did not appear to influence its success. There was no significant difference in the average age of coyotes shot ($\bar{x}$ = 2.6 years, SE = 0.3) or trapped ($\bar{x}$ = 2.9 years; SE = 0.3), the proportion of yearlings to adults shot (27% yearlings) or trapped (21% yearlings), or in the proportion of adult females with placental scars killed by shooting (75%) or by trapping (56%). The difference in sex ratios for coyotes killed using calling-and-shooting (80% males) and coyotes killed in traps (56% males) was significant ($\chi^2 = 4.25$; $P = 0.04$). There was no difference in the mean age of coyotes killed during SPM ($\bar{x}$ = 2.8, SE = 0.2) and coyotes killed by aerial hunting ($\bar{x}$ = 2.3, SE = 0.2; $P > 0.15$). The proportion of yearling coyotes killed by aerial hunting (43%) was higher than for coyotes killed during SPM (23%; $\chi^2 = 6.87$; $P = 0.01$). Sex ratios were equal for aerial hunting (44% males) and traps (56% males; $\chi^2 = 1.71$; $P = 0.19$), but there was a significant

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[3] Coauthored by Kimberly K. Wagner and Michael R. Conover.

difference in sex ratios between coyotes killed with aerial hunting and coyotes killed with calling-and-shooting (80% males; $\chi^2 = 11.96$, $P < 0.01$). There was not a difference in the proportion of adult females with placental scars between coyotes killed in SPM (62%) and coyotes killed with aerial hunting (63%; $P = 0.99$). There were no differences between coyotes killed during SPM in areas with and without consistent aerial hunting in age, sex ratio, or the proportion of yearlings. The higher proportion of yearling coyotes killed by aerial hunting may be attributable to seasonal differences in the coyote population, and not to differential vulnerability to the control techniques. Our results support the hypotheses that aerial hunting functions by removing coyotes difficult to catch using other management techniques and/or by reducing the density of breeding pairs (problem coyote and breeding pair hypothesis). However, our findings are not not strong enough to be certain that aerial hunting does not function by reducing local coyote populations (population control hypothesis).

Studies of lethal preventive predation management techniques indicate some methods effectively reduce sheep losses to coyote predation (C.J. Packham, USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID, 1973; Wagner 1997). Unlike corrective techniques that focus on stopping coyote predation after it starts, preventive techniques attempt to keep losses from starting. Although there is opposition to any lethal management technique, lethal preventive control methods are especially controversial because the relationship between the coyotes removed during preventive control and the coyotes causing depredations is unclear. Understanding the mechanisms for preventive predation management will improve the use of management tools, permit managers to better address concerns of critics of the program, and possibly indicate areas where nonlethal techniques could replace lethal methods (e.g., contraceptive techniques). Winter aerial coyote hunting, as used to prevent sheep losses in summer pastures of the Intermountain West, provides an opportunity to test hypotheses on the mechanisms for preventive predation management. Although it is one of the most efficient (coyotes/unit time) means of removing coyotes (J. H. Berryman, USDI Wildlife Services, unpubl. rep; USDI 1973a, b; Sterner and Schumake 1978; Wade 1978), its use is limited by many variables, including funding for aerial hunting, helicopter availability, and environmental requirements for safe, effective hunting (Wade 1976, USDI 1978). Consequentially, a better understanding of the mechanisms that make aerial hunting effective will aid managers in obtaining the most from available resources for aerial hunting.

Aerial hunting may impact sheep losses to coyote predation by temporarily reducing coyote populations (population control hypothesis; Wagner 1988), by reducing the number of adults with pups (breeding pair hypothesis; Till and Knowlton 1983, Messier et al. 1987), or by removing coyotes that have learned to avoid corrective control tools (problem coyote hypothesis). The population control hypothesis is the most common explanation for the effectiveness of preventive aerial hunting. According to this hypothesis, sheep losses to coyote predation are directly related to coyote density (Wagner 1988). With this hypthesis, 3 assumptions must be met for preventive control to be effective; (1) there must be a correlation between coyote population density and sheep losses, (2) the control technique must significantly reduce coyote population levels, and (3) losses to coyote predation must not be a compensatory form of mortality. Some evidence of a positive correlation between coyote densities and sheep losses to coyote predation exists from areas with differing coyote densities (Shelton and Klindt 1974, Robel et al. 1981, Wagner 1988) and for a single site in years with differing coyote densities by L.C. Stoddart and R.E. Griffiths (USDA Predator Ecology Center, Changes in jackrabbit abundance affect predation on sheep in southeastern Idaho, Logan, UT, 1986). Although sheep losses to coyote predation may, to some degree, be compensatory, there is no evidence this is true for all losses to coyote predation (O'Gara et al. 1983, Wagner 1997).

Aerial hunting is one of the most efficient (coyotes/unit time) means of removing coyotes, especially in areas with limited access or rough terrain, and would appear to have the potential to significantly reduce local coyote populations (J. H. Berryman, USDI Wildlife

Services, unpubl. rep; USDI 1973a,b; Sterner and Schumake 1978; Wade 1978). If the population control hypothesis is true, we anticipate a negative correlation between the intensity of coyote removal (coyotes killed/km^2) and sheep losses to coyote predation. Additionally, when sheep are killed by coyotes, ranchers usually ask ADC for assistance and ADC personnel often respond by using traps, snares, calling-and-shooting, and M-44's to try to kill the offending coyotes (henceforth called corrective summer predation management or SPM). Therefore, we also anticipate a negative correlation between aerial hunting and the hours of SPM required during the subsequent grazing season.

The timing of aerial hunting may be especially important for the population control hypothesis. Knowlton (1972) recommended scheduling removals so they occur after the main coyote dispersal period and prior to whelping. Removing coyotes at this time improves the probability that aerial hunting mortality will be additive and not compensatory to dispersal or other forms of mortality. Hunting at this time could also reduce the population by removing some of the offspring that would have been born during the subsequent whelping season. Peak seasonal dispersal periods have been defined as August-January for coyotes in Montana (Pyrah 1984), November-January for a Texas coyote population (Knowlton 1972), and August-December in California (Shivik et al. 1996). In a study by Davison (1980) of northern Utah and southern Idaho coyote populations, 57% of the emigration observed in a highly exploited coyote population occurred during December-January, and 28% occurred from September-October. In the lightly exploited population, 54% of the emigration observed occurred from September-November, and 31% was observed from late February through early April. Given that preventive aerial hunting for summer pastures in the Intermountain West occurs from January-March, coyote removals in March would appear to have the best probability of being an additive form of mortality.

Any reduction in coyote density from aerial hunting must last from the January-March hunting season until the summer grazing season (mid-June through September; Wade 1976, 1978, Wagner 1988). Given that areas with aerial hunting are often relatively small and surrounded by areas without aerial control (potential source populations), immigration may negate reductions in coyote density by the time the sheep arrive on the summer allotments. For example, in an unpublished study by E. M. Gese (USDA Predator Ecology Center, pers. commun.), a Colorado coyote population in a 340 km^2 area was reduced approximately 50% by January aerial hunting (based on scent station indices and density estimates). Territory size, pack size, and density estimates had returned to pretreatment levels within 4-5 months. Using this 4-5 month recovery period, coyote populations in areas receiving January aerial hunting would recover by May-June. Reductions occurring in March would have the best probability of lasting until late September when the sheep leave the summer grazing areas. If the population control hypothesis is correct, then there should be a negative correlation between the Julian date of aerial hunting and sheep losses to coyote predation.

The breeding pair hypothesis is based on data from Till and Knowlton (1983) indicating that many of the spring and summer coyote depredation problems may be caused by territorial adults with pups. In their study, depredation incidents within the ensuing week were reduced 98% when adults and pups were removed and 88% when only pups were removed. In all cases, depredations ceased within 3 days of control. Techniques that reduce the number of adults with pups should significantly reduce sheep losses to predation (breeding pair hypothesis). This could be accomplished through denning, the development of contraceptive techniques, or by disrupting breeding through the removal of 1 or both members of a pair. In the latter instance, coyote removal would have to be timed so there would be insufficient time for new breeding pairs to become established before the subsequent breeding season.

The January-March timing of aerial hunting includes the January and February breeding season (Knudsen 1976). Even if the last date for conception is extended to the end of March, the required duration for the population reduction would be 0-3 months instead of 3-6 months for the population control hypothesis. This difference in the necessary duration of effect is not required by the breeding pair hypothesis. Coyote densities could reach precontrol levels by the time sheep arrive on the allotment, but sheep losses would still be lower because there are fewer coyotes with pups in the population.

It is unclear whether this hypothesis requires a relationship between the intensity of coyote removal and sheep losses to coyote predation. The answer may depend on which coyotes are vulnerable to aerial hunting. We would anticipate that the higher the proportion of breeding adults killed by aerial hunting, the lower the likelihood there would be a correlation between the intensity of aerial hunting and sheep losses to coyote predation. The target coyotes (breeding adults) would be removed early in the hunting effort and, according to the breeding pair hypothesis, little would be accomplished by subsequent coyote removals. Data from a study by Knowlton et al. (1985) indicate that juveniles may be more vulnerable to aerial hunting than adults. Of 12 coyotes captured by aerial hunting, only 3 were >3 years old. However, 17 of 33 coyotes trapped and collared in the same area were >3 years of age. If, as proposed by Windberg and Knowlton (1990), juvenile and yearling coyotes are more vulnerable to traps, then the ratio of young coyotes trapped and marked in the study by Knowlton et al. (1985) is high. Consequently, the proportion of young coyotes killed by aerial hunting is additionally biased from the actual distribution within the population. For best results, the majority of depredating coyotes removed during SPM from areas without aerial hunting should be reproductively active.

As already mentioned, the problem coyote hypothesis assumes that aerial hunting removes sheep-killing coyotes that have learned to avoid other corrective control techniques. Personnel working with coyote predation management often assert that coyotes learn to avoid corrective control techniques like trapping and calling-and-shooting (Wade 1978). 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. To test the hypothesis, we assumed that older coyotes were more likely to be less vulnerable to corrective management techniques. Therefore, the average age of adult coyotes captured with aerial hunting should be older than for coyotes captured from areas during SPM in areas with aerial hunting. The problem coyote hypothesis can have, but does not require, a relationship between the timing of aerial hunting and sheep losses to coyote predation. However, since most new territory holders are likely to have been nonterritorial juveniles and yearlings (Knowlton 1972, Camenzind 1978, Gese et al. 1988), we would anticipate the average age of coyotes removed during SPM from areas with aerial hunting would be lower than for areas without aerial hunting. As with the breeding pair hypothesis, the relationship between hunting intensity and sheep losses to coyote predation will depend on which coyotes are vulnerable to aerial hunting.

These hypotheses are not mutually exclusive. Removal efforts that result in a significant and lasting reduction in coyote density also are likely to remove older coyotes and, depending on the timing of control, affect the density of adults with pups. However, the advantage of the problem coyote and breeding pair hypotheses is that coyotes can immigrate into the treated areas during the 3-6 months between treatment and grazing without negating the impact of the treatment. To test these hypotheses, we used data from field studies and the Utah ADC records to compare data on sheep losses to coyote predation and the need for SPM to the extent (coyotes killed, hours of aerial hunting) and intensity (coyotes killed/km^2, hours of aerial hunting/km^2) of aerial hunting. We also obtained data on the sex, age, and reproductive status of coyotes killed by aerial hunting and during SPM.

METHODS

Impact of Aerial Hunting Extent and Intensity on Lamb Losses and the Need for SPM

Field Study.--Data on the hours of aerial hunting per grazing area (allotment), allotment size (km^2), coyotes killed/allotment during aerial hunting, and timing of aerial hunting were obtained from 21 allotments with aerial hunting that were used in a field study by Wagner (1997). Three grazing areas were on privately owned pastures in in Iron County, Utah. The remaining areas were located in USFS lands in Utah and Idaho: the Teasdale (1 allotments) and Cedar (2) districts of the Dixie National Forest; the Price (3), Ferron (3), and

SanPete (3) districts of the Manti-LaSal National Forest; the Richfield (1) district of the Fishlake National Forest; the Heber (1) district of the Uinta National Forest; the Logan (2) districts of the Wasatch-Cache National Forest, the Soda Springs (2) district of the Caribou National Forest, and the Burley (1) district of the Sawtooth National Forest. For independent variables, we measured the extent of aerial hunting by assessing the hours of aerial hunting and the number of coyotes shot. Aerial hunting intensity was measured by determining the hours of hunting/km^2 and coyotes killed/km^2.

We defined aerial hunting success as a reduction in the number of lambs killed by coyotes and the need for SPM. Hence for each allotment, we measured the number of confirmed lamb kills by coyotes, estimated lamb losses to coyote predation, and the number of ewes and lambs lost to all causes as described by Wagner (1997). With the shepherd and livestock producers' assistance, we located the dead sheep and determined the cause of death (confirmed kill) using criteria described by Wade and Bowns (1985). Livestock producers were only able to locate a portion of the total number of sheep that died. Hence, the number of confirmed cases of coyote predation probably underestimates actual loss (Taylor et al. 1979, Scrivner et al. 1985). The following equation was used to estimate the total number of ewes (L_{ee}) or lambs (L_{el}) likely to be killed by coyote predation during the study period

$$L_{ee} \text{ or } L_{el} = C_{cs} + (C_{cs}/L_{ks})L_{us},$$

where C_{cs} is the number of confirmed coyote kills (lambs or ewes), L_{ks} is the known number of lamb or ewe deaths to all causes, and L_{us} is the number of sheep missing at the end of the study period.

We assessed the relationship between aerial hunting and SPM by using the number of hours of SPM, the number of coyotes killed during SPM, and the number of the nights of trap, snare, and M-44 use (device nights). Device nights are an alternative measure of SPM and serve as an index of nontarget risk because these tools catch species other than coyotes.

Device nights were calculated by multiplying the number of traps, snares, and/or M-44's used by ADC specialists by the number of nights they were used. We also calculated the intensity of SPM (hours of SPM/km^2, coyotes killed during SPM/km^2). The impact of aerial hunting on SPM is important because SPM is less efficient in removing coyotes (cost and time/coyote killed), and because some SPM tools (traps, snares, and M4-4's) risk capturing nontarget species (USDI 1978, USDA 1994). Data were analyzed for correlations among measures of the extent, intensity, and timing of aerial hunting and the measures of sheep losses and SPM using Spearman's rank correlation analysis (Steele and Torrie 1980).

Assessment of ADC Records.-- We were able to obtain data from the Utah ADC field specialists' work records for the Wasatch-Cache, Uinta, Dixie, and Manti National Forests for 1990-1994. These data did not include information on the device nights or estimated losses, but we were able to get information on allotment size, extent of aerial hunting (hours of aerial hunting), hunting intensity, hunting efficacy, kill intensity, and hunting efficiency.

Sheep losses to predation and SPM were measured using data on confirmed (by ADC personnel) lamb losses to coyote predation, reported (by sheep producers) losses of lambs to coyote predation, and lamb and ewe losses to all causes, hours of SPM, coyotes killed during SPM, and intensity of SPM. Data on timing of aerial hunting, estimated lamb loss to coyote predation, and device nights were not available for this data set. Data for areas reporting losses to mountain lions (Felis concolor) or bears (Ursus spp.) were not used because ADC records did not differentiate between the hours spent working on these species and hours spent working on coyote problems. Successful aerial hunting ($\geq$1 coyote killed) occurred in 75 of these sets of observations. We then used the Spearman's rank correlation analysis to test for significant correlations between independent and dependent variables.

Impact of Timing of Aerial Hunting on Lamb Losses and the Need for SPM

Aerial hunting occurred each year from 1 Jan-30 March, but sheep were placed in these allotments and SPM occurred from 1 June-30 September. We hypothesized that the later aerial hunting occurred on an allotment, the more effective it would be in reducing lamb losses and the need for SPM. To assess this, we used data obtained from the field study by expressing the date on which hunting occurred in each allotment in Julian days. If aerial hunting occurred on >1 date, the last date of successful aerial hunting was used for analysis. We then used the Spearman's rank correlation analysis to test the allotment data for significant correlations between the Julian date of hunting and dependent variables measuring lamb losses and the use of SPM.

Comparison of Coyotes Killed by Aerial Hunting and SPM Techniques

Coyotes Killed During SPM.--We obtained lower jawbones from coyotes killed during SPM from ADC field specialists. These animals were killed through the use of calling-and-shooting (hereafter referred to as shooting), traps, and snares. In 1993 and 1994, coyotes were taken in the Wasatch, Manti La-Sal, and Caribou National Forests. In 1995, coyote collection was expanded to include other sites in Utah and Idaho where there had been no aerial hunting for several years. ADC field specialists recorded the sex of the coyote and checked for evidence of reproduction (nursing, placental scars) in females. Coyotes were aged by removing canine teeth from lower jawbones and processing them using methods described by Linhart and Knowlton (1967) and Knudsen (1976).

Coyotes Killed by Aerial Hunting.--During 1993-1995, Utah and Idaho ADC field specialists provided carcasses of coyotes killed during aerial hunting (conducted in January - February) from the Wasatch, Manti La-Sal, and Caribou National Forests. Lower jawbones were obtained from all coyotes. Female reproductive tracts were frozen until examination for evidence of placental scars and implantation sites. Ovaries were stored in a 90% alcohol solution until they could be sectioned and examined for evidence of corpra lutea and corpra rubra (Knudsen 1976). Placental scars could not be used as a reliable indicator of litter size due to problems with fading of scars by the time aerial hunting occurred. Delays between aerial hunting and the time we received some carcasses resulted in decay, which also made use of corpra rubra and placental scars of questionable value. Therefore, the use of corpra rubra, corpra lutea, enlargement of the uterine walls, and placental scars was limited to providing evidence of prior reproductive effort. Canine teeth were treated in the same manner described above.

Data Analysis.--We combined data on coyotes killed by trapping or snaring into a single category (henceforth called trapping) because only 4 coyotes were killed by snares. When comparisons were made between aerial hunting and SPM, coyotes killed by SPM were grouped into a single category if there were no significant differences between trapping and shooting for the dependent variable being analyzed. Sample sizes were too small to compare the age distributions or the proportion of adult females with placental scars between coyotes killed during SPM in areas with and without consistent aerial hunting.

Data from studies by Bowen (1982), Allen and Kohn (1976), and Knudsen (1976) indicated that annuli may develop during the period between aerial hunting and corrective control. To account for the difference in time between preventive and corrective control tools, we defined pups as coyotes < 0.6 months in age (only in SPM samples), yearlings as coyote from 0.6 to 1.6 months in age, and adults as coyotes > 1.6 months. Age data were not normally distributed so a Mann-Whitney test was used to test for differences in the average age of adult coyotes captured through aerial hunting, traps, and shooting (Steele and Torrie 1980). Chi-square analysis was used to test for differences in the proportion of adults in each age class between aerial hunting and SPM tools.

We used a chi-square analysis to determine if the sex ratio of coyotes removed through aerial hunting, trapping, and shooting was equal (Steele and Torrie 1980). Similar tests were used to compare the proportion of yearlings captured using traps and shooting to the proportion of yearlings killed with aerial hunting. Due to the relatively low number of observations, Fisher's exact probability test (Steele and Torrie 1980) was used to compare the proportion of females with and without placental scars in samples obtained through aerial hunting and SPM.

RESULTS

Impact of Aerial Hunting Extent and Intensity on Lamb Losses and the Need for SPM

Field Study.--The general relationships between the extent of aerial hunting and the dependent variables measuring lamb losses and SPM were positive (14 of 16 relationships). However, none of the 16 relationships were statistically significant (Table 4.1). Likewise, the general relationship between the intensity of aerial hunting and the dependent variables was positive (15 of 16 relationships). However, only one of them was statistically significant (Table 4.1).

Assessment of ADC Records.--There were no consistent correlations in the data from ADC records between the extent of aerial hunting and lamb losses or the need for SPM (Table 4.2). However, there was a significant negative correlation between aerial hunting hours/km^2 and reported lambs killed by coyotes. Most of the correlations between the extent of aerial hunting and the dependent variables were positive while most correlations between the intensity of aerial hunting and the dependent variables were negative.

Impact of Timing of Aerial Hunting on Lamb Losses and the Need for SPM

For the 21 study allotments, the last date for aerial hunting occurred in January at 6 sites, February at 12 sites, and March at 3 sites. Successful aerial hunting occurred on >1 date on 46% of the sites. Timing of aerial hunting was not significantly correlated with any measure of sheep loss to coyote predation or measure of SPM ($P \geq 0.69$, Table 4.1).

Comparison of Coyotes Killed by Aerial Hunting and SPM Techniques

Carcasses of 102 coyotes killed by aerial hunting were obtained. We ascertained the sex and age of all coyotes, and the reproductive status of all 30 adult and 27 yearling females in the sample. Sixty-nine coyotes were killed by SPM: 35 in traps, 4 in snares, and 30 by shooting. Of these, we identified the age and sex of all coyotes, and the reproductive status of 13 of 20 adult and 2 of 3 yearling females.

Coyotes Killed During SPM.--There was no difference in the average age of coyotes killed with traps and shooting ($\underline{P} \geq 0.43$; Table 4.3) or in the age of adult coyotes killed by these 2 methods ($\underline{P} = 0.64$; Table 4.3). The proportion of yearling coyotes killed by trapping and shooting was similar ($\chi^2 = 0.44$; $\underline{P} = 0.50$; Table 4.4). There was no significant difference in the proportion of adult coyotes in each age class between the 2 techniques ($\chi^2 \leq 1.40$; $\underline{P} \geq 0.24$; Figure 4.1) The difference between the 0.79 male:female ratio of coyotes killed in traps and the 4.0 ratio for coyotes killed by shooting was significant ($\chi^2 = 4.25$; $\underline{P} = 0.04$; Table 4.4).

Three of 4 adult females taken by shooting for which we have reproductive data had placental scars, as did 5 of 9 adult females taken in traps. This difference was not statistically significant ($\underline{P} = 0.99$).

Coyotes Taken by SPM and Aerial Hunting.--The mean age of all coyotes and adult coyotes taken by aerial hunting was not significantly different from coyotes killed in SPM ($\underline{P} > 0.15$; Table 3.3). However, yearlings were more vulnerable to aerial hunting than SPM ($\chi^2 = 6.87$; $\underline{P} = 0.01$; Table 3.3). There was no significant difference between the age distribution of adult coyotes captured with aerial hunting and coyotes captured in traps ($\chi^2 \leq 1.23$; $\underline{P} \geq 0.27$; Figure 3.1). However, the difference in the proportion of adult coyotes in the > 3 and > 4 year (summer ages) age classes between coyotes killed with aerial hunting, and coyotes killed by shooting approached significance (coyotes > 3 years $\chi^2 = 3.62$, $\underline{P} = 0.06$; coyotes > 4 years $\chi^2 = 3.23$, $\underline{P} = 0.07$; Figure 3.1).

The 0.79 male/female ratio of coyotes taken by aerial hunting did not differ from the 1.3 male/female ratio for coyotes taken in traps ($\chi^2 = 1.71$; $\underline{P} = 0.19$), but did from the 4.0 male:female ratio of coyotes taken by shooting ($\chi^2 = 11.96$; $\underline{P} < 0.01$).

Nineteen of 30 adult females taken by aerial gunning had placental scars as did 8 of 13 adult females taken by SPM. This difference was not statistically significant ($\underline{P} = 0.99$).

Coyotes Taken by SPM in Areas With and Without Aerial Hunting.--There was no difference in the average age of all coyotes or adult coyotes taken during SPM in areas with and without consistent aerial hunting programs ($\underline{P} \geq 0.26$; Table 3.3). There was no significant difference in the proportion of yearlings in either sample ($\chi^2 = 0.55$; $\underline{P} = 0.46$; Table 3.4) or in their age distribution. There was also no significant difference in the ratio of males to females in the samples ($\chi^2 = 0.01$; $\underline{P} = 0.94$; Table 3.4).

DISCUSSION

Impact of Hunting Extent, Intensity, and Timing on Lamb Losses and the Need for SPM

We found no consistent relationship between extent and intensity of aerial hunting and lamb losses or the need for SPM. Two hypotheses could explain the absence of a consistent relationship between aerial hunting and sheep losses or SPM. The first is that aerial hunting is ineffective. However, this hypothesis seems unlikely because Wagner (1997) compared lamb losses on allotments receiving aerial hunting to those that did not and found that aerial hunting reduced both lamb losses and the need for SPM. A 1973 evaluation of a combined preventive and corrective aerial hunting program by C.J. Packham (USDI Wildl. Serv., Coyote damage control with helicopters in selected areas of Idaho, Boise, ID) also found lower sheep losses to coyote predation in areas with aerial hunting. The second hypothesis is that the helicopter crews knew where coyote predation was heaviest the year before and were more willing to spend extra time hunting in "problem" allotments than others. This hypothesis seems likely given that aerial hunting was conducted and directed by the local ADC specialists who had such knowledge. Several field specialists informed us that this is their practice. This could also be readily tested by looking for a correlation between the extent and intensity of aerial hunting and the prior season's lamb losses to coyote predation. Such a pattern should produce a positive correlation between the extent and intensity of aerial hunting and lamb losses and the need for SPM if aerial hunting was ineffective. However, our data showed the lack of either a positive or negative correlation between the extent and intensity of aerial hunting and lamb losses or the need for SPM. We interpret this to mean that aerial hunting is successful in reducing coyote predation in problem allotments but not in eliminating it entirely. Hence, it can be inferred that by concentrating activity in these problem allotments, aerial hunting tends to reduce the inherent problems associated with them, making all allotments more or less equal in their potential for predator problems during the subsequent grazing season.

Errors in estimating the area covered by aerial hunting and in the scale of the study may have contributed to the lack of consistent relationships between hunting and sheep losses, especially with data from the ADC records. It was impossible to obtain an exact measure of the area of an allotment covered by aerial hunting teams. Instead, we used the area of the entire grazing allotment. The scale of our study may also have been a problem in that aerial hunting continued beyond the boundaries of our study allotments. The amount of area and the intensity of coyote removal outside our study sites can have a substantial impact on the success of aerial hunting within the study sites (Knowlton 1972, Stoddart et al. 1989). The removal of coyotes from buffer zones around areas to be protected has been recommended by some authors (Knowlton 1972, Wade 1976) and may be especially important when treatment areas are relatively small compared to the movement patterns of the target species (Stoddart et al. 1989).

As used by Utah ADC, the timing of aerial hunting did not influence its success. This indicates that further restrictions on when this type of aerial hunting can occur are unwarranted. In general, however, the importance of the timing of aerial hunting will depend on the mechanism(s) that make preventive control an effective technique. If the breeding pair hypothesis is true, then control will have to be confined to the breeding season.

Comparison of Coyotes Killed with Aerial Hunting and SPM Techniques

The approximate 1:1 sex ratio of coyotes killed with traps and aerial hunting was as expected given the equal sex ratios reported by Windberg and Knowlton (1990) in their review of the relative vulnerability of coyotes to these management tools. Many studies on established coyote populations have found an equal sex ratio (Davison 1980, Todd et al. 1981, Moore and Millar 1984, Gese et al. 1988). In contrast, we found that males were particularly vulnerable to shooting. The shooting technique used in our study took advantage of territory/pup defense behavior of the adults. Given that males were involved in >90% of the territorial encounters observed by Gese (USDA Predator Ecology Center, pers. commun.), the large proportion of males observed in our sample is not surprising. Additionally, M. Bodenchuk (Utah ADC, pers. commun.) indicated that ADC specialists using shooting will selectively try to kill the males because the specialists believe males are responsible for more problems than females. Unlike our study, Windberg and Knowlton (1990) did not observe a difference in the sex ratio of coyotes killed using shooting. This difference may be because rabbit distress calls were used in the study by Windberg and Knowlton (F. F. Knowlton, pers. commun), but pup distress calls, adult coyote calls, and specially trained dogs were used as lures for coyotes during the shooting in our study.

The proportion of yearlings in the sample of coyotes collected by aerial hunting from January-February in our study (45%) was similar to the proportion of same-age juvenile (called yearlings in our study) coyotes (49%) captured primarily by aerial hunting in 1972-73 and the overall proportion of juvenile coyotes (48%) captured in winter using all techniques in a study conducted in Curlew Valley Idaho by Knudsen (1976). However, it is lower than the proportion of juvenile coyotes trapped in the fall from the same area (Davison 1980) for areas with and without predator control (80% with control and 62% without control). Potential reasons for the decline in the ratio of juveniles from the fall-trapped sample to the aerial-hunted samples include mortality in dispersing juveniles during the period between fall trapping and the winter collections, and a greater vulnerability of juveniles to traps (Knudsen 1976). The proportion of yearlings in SPM samples from our study (23%) was similar to the 14-26% of yearlings in spring samples obtained by Knudsen (1976), and the 11-17% yearlings in the samples of trapped coyotes killed from September-October in the study by Davison (1980).

Knudsen (1976) reported that the proportion of juveniles in a coyote population in northern Utah/southern Idaho fluctuated from 42% in December to 25% in April. This difference in the ratio of juveniles to adults is similar to our observed ratio of yearlings (same age as juveniles in Knudsen [1976]) to adults in coyotes killed with winter aerial hunting and yearlings to adults (same age class) in coyotes killed with traps during summer. Therefore, we believe that our observation of a higher proportion of yearlings in the aerial hunting sample than the SPM may reflect changes in the population rather than differential vulnerability of yearlings to the control tools.

Given that calling-and-shooting is designed to exploit a coyote's territorial behavior, we were surprised that the proportion of yearlings in the samples obtained by shooting were similar to those obtained by trapping. Yearlings captured by SPM in our study were not likely to be reproductively active and would only have been beginning to establish territories (Gantz 1990). If calling-and-shooting gets more adult territorial coyotes than juveniles, then our findings also differ from the hypothesis presented by Windberg and Knowlton (1990) that juvenile and yearling coyotes are more vulnerable to traps than adults. Alternatively, some yearling coyotes may help defend their parents' territory from intruders and therefore may be more vulnerable to calling-and-shooting.

In the absence of data on the actual age structure of the coyote populations in our study, the impact of aerial hunting on coyote populations remains unclear. However, our findings provided additional evidence of differential vulnerability of coyotes of different age classes to management tools and reinforces the need to use caution when extrapolating age structure data obtained using any 1 sampling technique to that of the entire population.

Test of Hypothesis

Our data provides some insight as to the mechanisms that may make aerial hunting an effective management tool. We predicted a relationship between the extent and intensity of aerial hunting and lamb losses to coyote predation and the hours of SPM if the population control hypothesis were true. We also expected a relationship between the timing of aerial hunting and the sheep losses and hours of SPM. Our data did not provide any evidence of these relationships. However, as mentioned above, there were several factors which may have confounded our results; therefore, this hypothesis cannot be completely discounted.

Although our data are not sufficient to disprove the population control hypothesis, data from two other studies also cast doubt on this hypothesis. Davison (1980) found no difference in coyote densities during spring or fall between an area that received little to no predator control and an area where coyote mortality from hunting was 50% higher in 1 year and 360% higher in another year. In an unpublished report by E.M. Gese (USDA Predator Ecology Center, pers. commun.), a Colorado coyote population in a 340-km^2 area was reduced approximately 50% by January aerial hunting (based on scent station indices and density estimates). Within 4-5 months, territory size, pack size, and density estimates had returned to pretreatment levels. Given this sort of recovery time, the population control hypothesis would predict that late-season hunting would be more successful than early-season hunting but such was not observed in this study.

The breeding pair hypothesis was based on data provided by Till and Knowlton (1983) in which the majority of sheep losses appeared to be attributable to adult coyotes with pups. Given the January-February conception dates for Utah coyotes (Knudsen 1976) and the January-March dates for aerial hunting, we did not anticipate a relationship between the timing of aerial hunting and sheep loss to predation. The findings of this study support this hypothesis.

Unlike the population control hypothesis, the breeding pair hypothesis does not predict a relationship between the extent and intensity of aerial hunting and sheep losses to coyote predation. It seems likely that as the number of coyotes removed from an area increases, the greater the probability that the reproductively active adults have been removed. However, if the reproductively active adults are amongst the first to be removed from an area, additional removals will not necessarily result in a decrease in losses, and a correlation would not be observed. The answer may depend on which coyotes are vulnerable to aerial hunting: the greater the proportion of reproductively active adults in the samples captured by aerial hunting, the less important the relationship between extent and intensity of control and sheep losses. In our study, 55% of the coyotes removed through aerial hunting were of age to form successful breeding pairs based on data from Knudsen (1976) and Gantz (1990). This ratio is higher than might be expected given the limited data previously available from Knowlton et al. (1985) and may be sufficiently high to make a relationship between the extent and intensity of aerial hunting and sheep losses or hours of SPM unlikely.

The problem coyote hypothesis also did not require a relationship between the extent, intensity, or timing of aerial hunting and sheep loss to predation, as was the case in our study. Support for the problem coyote hypothesis can be found in the trend for a higher proportion of older coyotes in the sample captured with aerial hunting than SPM, especially coyotes killed with shooting. The potential difference in age of coyotes killed between aerial hunting and shooting is especially important for areas of Utah's National Forests where recreational use is high and ADC field specialists primarily use shooting because of the reduced risk to nontarget species. We also anticipated that the age of coyotes removed during SPM should be lower in areas with consistent aerial hunting. This was not supported by our results although the data indicated a trend in this direction. Our sample size was relatively small (38 coyotes) and additional data will be needed before this question can be adequately addressed.

The hypotheses are not mutually exclusive, and a technique that significantly reduces the coyote population will also probably reduce the proportion of older, more experienced coyotes in the population (problem coyote hypothesis). Depending on the timing of control, a technique significantly reducing the coyote population could also reduce the number of breeding pairs. With aerial hunting, different mechanisms may be in effect in different areas. For a large area with a high intensity of coyote kills, it may be possible to control the coyote population, but for smaller areas the breeding pair or problem coyote hypotheses may be the more likely mechanisms. For aerial hunting as used in our study, our findings provide some support for the latter 2 theories. If the breeding pair hypothesis is true, then the possibility exists that alternative nonlethal methods of reducing the number of breeding adults (e.g., chemosterilants, immunocontraception) may achieve similar results as lethal preventive control. If the problem coyote hypothesis is true, then emphasis should be placed on making a wide variety of techniques available for predation management.

MANAGEMENT IMPLICATIONS

We were unable to identify a consistent relationship between the extent and intensity of aerial hunting and subsequent lamb losses or the need for corrective predation management. The most logical explanation for this is that aerial hunting is concentrated in problem allotments with consistent high losses to coyote predation. Aerial hunting reduces losses in these areas but may not bring losses to levels below that of other areas with fewer problems.

As used in our study, the timing of aerial hunting as practiced by Utah ADC did not influence its success. If aerial hunting was effective because it removed specific coyotes that were lamb-killers, but had learned to avoid the techniques employed during summer predation management (snares, traps, and M-44's), or if it reduced the number of breeding pairs, then such a relationship may not exist.

Differences in the proportion of yearlings killed by aerial hunting and SPM, and the difference in sex ratio between calling-and-shooting and all other techniques support the findings of Windberg and Knowlton (1990) that there is differential vulnerability to coyote capture techniques. Care should be taken in selecting the sampling technique and when extrapolating information from a sample collected with only 1 technique to the entire population. However, although aerial hunting removes a higher proportion of yearlings than SPM, data from our study as well as data from Knudsen (1976) indicate this does not necessarily mean aerial hunting kills a disproportionately high number of yearlings relative to other control techniques. This difference may result from a decrease in the proportion of yearlings in the population resulting from high yearling mortality rather than a differential vulnerability of yearlings to aerial hunting.

The trend to a higher average age distribution for adult coyotes removed through aerial hunting than through SPM is expected if aerial hunting captures older coyotes that are less vulnerable to other control tools (problem coyote hypothesis). We also hypothesized that the average age of coyotes in areas with consistent aerial hunting programs might be lower than for areas without consistent aerial hunting. Our data indicate a trend in this direction but the difference was not significant and the sample size was limited. Additional information will be needed before this question can be answered.

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Table 4.1. Values ρ from Spearman's rank correlation analysis for relationships among measures of aerial hunting and sheep losses to coyote predation and the need for corrective summer predation management using data from field studies (1993-1995). Measurements were from the period of 1 June - 30 September.

	Timing of aerial hunting[a]	Extent of aerial hunting		Intensity of aerial hunting	
		Hours	Coyotes killed	Hours/km^2	Coyotes killed/km^2
Lamb losses					
Confirmed kills by coyotes	-0.11	0.14	0.14	0.21	0.20
Estimated kills by coyotes[b]	0.04	0.21	-0.62	0.28	0.02
Losses to all causes	-0.11	0.60	0.33	0.07	0.14
Extent of corrective summer predation management					
Hours	-0.01	0.32	0.19	0.05	-0.01
Device nights	-0.05	0.42	0.41	0.34	0.42
Coyotes killed	-0.01	0.01	0.17	0.22	0.18
Intensity of corrective summer predation management					
Hours/km^2	-0.08	0.22	0.18	0.51*	0.41
Coyotes killed/km^2	0.05	-0.01	0.26	0.43	0.42

[a] Date expressed in Julian days for analysis.

[b] Total losses to coyote predation estimated using methods described by Wagner 1997.

* $P < 0.05$

Table 4.2. Relationships between extent and intensity of aerial hunting, and lambs lost to coyote predation and the need for corrective summer predation management using data from Utah Animal Damage Control Program (1990-1994). Measurements were from the period of 1 June - 30 September. Reported values are ρ from Spearman's rank correlation analysis.

	Extent of aerial hunting		Intensity of aerial hunting	
	Hours	Coyotes killed	Hours/km²	Coyotes killed/km²
Lamb losses				
Confirmed kills by coyotes	0.10	0.19	-0.10	-0.01
Reported kills by coyotes[a]	-0.12	0.02	-0.28*	-0.15
Losses to all causes	-0.07	-0.03	-0.16	-0.11
Extent of corrective summer predation management				
Hours	0.18	0.18	-0.07	-0.07
Coyotes killed	0.04	0.13	-0.07	-0.02
Intensity of corrective summer predation management				
Hours/km²	0.16	0.16	0.13	0.12
Coyotes killed/km²	0.02	0.10	-0.01	0.02

[a] Livestock producer reported estimates of total losses to coyote predation.

* $\underline{P} \leq 0.05$

Table 4.3. Age of coyotes killed using aerial hunting and various corrective summer predation management techniques in Utah and Idaho (1993-1995).

	All coyotes			Adult coyotes		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Comparison of corrective summer predation management techniques (SPM)						
Traps[a]	39	2.9	0.3	30	3.6	0.3
Shooting	30	2.6	0.3	21	3.3	0.4
Total SPM	69	2.8	0.2	51	3.5	0.3
Comparison of aerial hunting and corrective summer predation management techniques						
Aerial hunting	102	2.3	0.2	58	3.7	0.3
Total SPM	69	2.8	0.2	51	3.5	0.3
Comparison of coyotes killed during summer predation management in areas with and without aerial hunting						
With aerial hunting	13	2.3	0.4	9	2.9	0.4
Without aerial hunting	25	3	0.4	20	3.6	0.5

[a] Includes 4 coyotes captured using snares.

Table 4.4. Sex and age classes of coyotes killed using aerial hunting and various corrective summer predation management techniques in Utah and Idaho (1993-1995).

		% in each age class				% of each sex	
	n	Pups	Yearlings	Adults		Male	Female
Comparison of corrective summer predation management techniques (SPM)							
Traps[a]	39	2	21	76		56[b]	44[b]
Shooting	30	1	27	70		80[b]	20[b]
Total SPM	69	3	23	74		67	33
Comparison of aerial hunting and SPM techniques							
Aerial hunting	102	0	43[d]	57		44[c]	56[c]
Total SPM	69	3	23[d]	74	Traps	56	44
					Shooting	80[c]	20[c]
Comparison of Coyotes Killed during Summer Predation Management in areas with and without aerial hunting							
With aerial hunting	13	0	31	69		69	31
Without aerial hunting	25	0	20	80		68	32

[a] Includes 4 coyotes captured using snares.

[b] Proportion of males to females different between traps and calling-and-shooting (P = 0.04).

[c] Proportion of males to females different between aerial hunting and calling-and-shooting (P < 0.01).

[d] Proportion of yearlings different between aerial hunting and corrective summer predation management (P = 0.01).

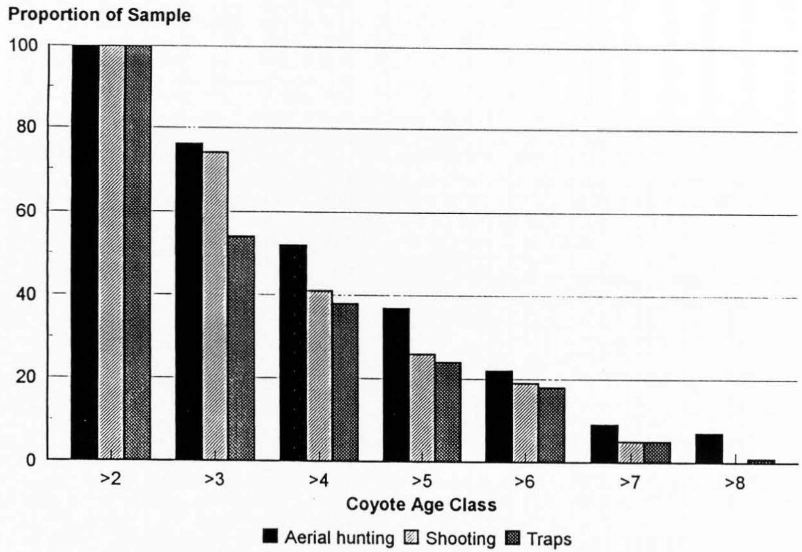

Fig. 4.1. Age distributions of adult coyotes captured with winter aerial hunting and various corrective summer predation management techniques in Utah and Idaho (1993-1995).

CHAPTER 5

COMPENSATION PROGRAMS FOR WILDLIFE DAMAGE IN NORTH AMERICA[4]

Abstract: Financial compensation for damages caused by wildlife is an intuitively appealing alternative to lethal wildlife damage management techniques, but opinions are mixed as to the value of these programs. Additionally, little is known about the use of financial compensation programs in North America. We sent surveys to all states and the Canadian provinces requesting information on the wildlife species and type of damage covered by compensation programs, the annual cost of the programs, and the monitoring and assessment of program success. We also requested information on programs providing producers with damage-abatement materials instead of, or in addition to, financial compensation. All states and provinces responded to our survey. Nineteen states and 7 provinces had compensation programs, and 34 states and 7 provinces provided damage-abatement materials. Most programs were funded by the state but private and federal organizations also funded some programs. Programs for damage by deer (Odocoileus spp.) were the most common (14 s/p), followed by bear (Ursus spp.- 12 s/p), elk (Cervus elaphus - 10 s/p), moose (Alces alces - 7 s/p), waterfowl (6 s/p), pronghorn antelope (Antilocarpa americana - 6 s/p), wolves (Canis spp. - 5 s/p), mountain lions (Felis concolor - 4 s/p), and coyotes (Canis latrans - 3 s/p). Compensation programs involving ungulates included damage to cultivated crops (all 15 s/p), standing hay crops and pastures (5 s/p), stored hay (6 s/p), and damage to other property including fencing and irrigation equipment (8 s/p). Programs for predators involved livestock losses, and programs for bears involved damage to crops, livestock, and beekeeping equipment. In general, compensation programs were established for problems that were recent in origin, resulted from governmental actions, and/or were caused by highly valued species. Few states or provinces had formal evaluation procedures for their programs. Given the expense of compensation

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[4]Coauthored by Kimberly K. Wagner, Robert H. Schmidt, and Michael R. Conover

programs and the divided opinions about the programs, we recommend that all states and provinces implement a formal review system.

Wildlife damage management techniques can be divided into 3 general categories: managing the offending animal or its habitat, modifying human activities, and increasing human tolerance of wildlife problems. Compensation programs fall in this last category and involve paying agricultural producers for all or a portion of the value of crops, property, or livestock damaged by wildlife.

One advantage of compensation programs is that they eliminate the risk of direct injury to humans and wildlife from damage management tools like traps and pesticides and may increase landowner tolerance of problems with threatened or endangered species (Olsen 1991). Compensation may also be a useful tool in situations where private lands include, or are adjacent to, habitat critical for the well-being of a wildlife species or population (Van Eerden 1990, Olsen 1991, Rimbey et al. 1991). Payment programs have been used in areas where the public places a high monetary value on game species, and license revenues may be used to pay for damages caused by game species (Engle 1963, Rimbey et al. 1991). In 1946, all 10 state compensation programs were for damages caused by game species (McDowell and Pillsbury 1959).

Not all opinions regarding compensation programs are positive (Olsen 1991). McIvor and Conover (1994) asked northern Utah and southern Idaho farmers and nonfarmers their opinion of hunting and compensation as solutions to damage caused by sandhill cranes (Grus canadensis). Sixty-nine percent of farmers and 50% of nonfarmers approved of hunting, while only 32% of farmers and 23% of nonfarmers approved of compensation programs. In a survey requesting opinions on paying livestock producers for sheep killed by coyotes with general tax monies, only 11% of sheep producers, 7% of cattlemen, and <26% of the general public expressed any form of approval (Kellert 1979). Additionally, compensation programs rarely pay producers for the full value of all indirect and direct costs associated with wildlife damage.

Although compensation programs are an intuitively appealing alternative to more traditional lethal management options, they are not suitable for all situations (Musgrave and Stein 1993, United States Department of Agriculture [USDA] 1994). Compensation does not stop the damage problem and may not be appropriate in situations where wildlife causes a risk to human health and safety (USDA 1994). Likewise, producers with a sense of responsibility for the well-being of their livestock may be less likely to accept compensation programs than producers with damage to crops. Failure to address problems attributable to high wildlife densities and continued population growth may result in harm to the problem species, local vegetation, and other associated wildlife as well as increased damage (USDA 1994). Engle (1963: page 105) expressed the opinion of some resource managers as, "The State's right of trust is to regulate and control the harvests and preservation of game; and the state is not responsible for damages caused by game." He believed that compensation programs were an inappropriate wildlife management practice and a system vulnerable to abuse.

At a time of increasing budget constraints, the financial burden of compensation programs may be unacceptable (Van Eerden 1990, Olsen 1991, Rimbey et al. 1991). In a 1990 survey of U.S. programs for crop damage by large mammals, Wisconsin reported payments for compensation and damage prevention materials of $920,000 in an average year, with a high of $2,350,000 (M. Whitt, L.W. Adams, and J.P. Linduska, Young hunter programs and large mammal crop depredation control. Nat. Res. Manage. Prog., Univ. Maryland, College Park, 1993). Idaho paid $500,000 in claims for damage occurring from July-December, 1988 (Rimbey et al. 1991). In the Environmental Impact Statement of the Animal Damage Control program, the USDA estimated that over $500 million would been needed annually to replace current damage management techniques with a compensation program (USDA 1994). Additional funds would be needed for program administration and damage verification. States may also be unwilling to justify compensation for damage by 1 species and not others (Olsen 1991).

To gain more information on the situations where compensation is a viable alternative, we surveyed U.S. state and Canadian provincial wildlife and agriculture agencies for information on programs providing compensation or materials for wildlife damage prevention. We also examined several hypotheses to explain why some wildlife damage situations are covered by compensation programs and others are not.

METHODS

We sent surveys in January 1994 to state and provincial wildlife agencies in the U.S. and Canada. All agencies had responded after 2 additional mailings of the survey. We discovered incomplete responses in some states where we were familiar with the available programs. To check response accuracy, the same survey was sent to all state and provincial agriculture agencies in January 1995. Agricultural producers comprise the group most affected by compensation programs and some programs are funded by state agriculture agencies. An additional survey requesting a listing of the species involved in compensation programs and the agency administering the program was sent to each state USDA, Animal and Plant Health Inspection Service (APHIS), Animal Damage Control (ADC) office. After 2 additional mailings, we received a 100% response from state ADC offices and a 71% response from state agriculture agencies.

The survey sent to the wildlife and agriculture agencies requested information on the species involved in compensation programs, the type of damage covered, and the amount of money spent on compensation. Given the conflict in opinions over the value of compensation programs, we asked if the agency had conducted an attitudinal survey of participants or the general public toward the program and if the agency had plans to do so in the next 5 years. We also requested information on compensation programs funded by other agencies and on any programs that may have been canceled. Many compensation programs incorporated provisions for providing damage prevention materials. Respondents were asked to provide information on any programs that provided supplies or financial assistance for damage management tools.

RESULTS

For every state/province, responses from all 3 agencies were compiled into a master list of compensation programs. When compared to the master list for the state, 8% of the wildlife agencies, 12% of the agriculture agencies, and 9% of the state ADC programs failed to list all available programs in their state/province.

Nineteen states and 7 provinces listed compensation programs. Most programs were funded or administered by the state or provincial wildlife or agriculture agencies (Table 5.1). However, a nongovernmental organization, Defenders of Wildlife, had a compensation program for gray wolf (Canis lupus) predation on livestock in Idaho, Montana, and Wyoming, and was developing a program for the proposed introduction of Mexican wolves (C. lupus baileyi) in Arizona and New Mexico (H. Fisher, Defenders of Wildlife, Missoula MT, pers. commun.). In Montana, the Great Bear Foundation paid producers for livestock killed by grizzly bear (Ursus arctos), and the U.S. Fish and Wildlife Service pays producers for livestock killed by reintroduced red wolves (C. rufus) in North Carolina. Environment Canada pays 50% of the cost for damage prevention materials and compensation programs related to damage caused by waterfowl (Table 5.1).

Deer (Odocoileus spp.) were the most common species in compensation programs (14 states and provinces [s/p]) followed by bear (Ursus spp.- 12 s/p), elk (Cervus elaphus - 10 s/p), moose (Alces alces - 7 s/p), waterfowl (6 s/p), pronghorn antelope (Antilocarpa americana - 6 s/p), wolves (Canis spp. - 5 s/p), mountain lions (Felis concolor - 4 s/p), and coyotes (Canis latrans - 3 s/p; Table 5.1). Upland game birds, wood bison (Bison bison athabascae), grizzly bear, bighorn sheep (Ovis canadensis), mountain goat (Oreamnos americanus), cranes, and beaver (Castor canadensis) were mentioned in only 1 or 2 states or provinces (Table 5.1). Maine, New Brunswick, New York, and Pennsylvania compensated owners for livestock lost to predation by domestic dogs.

Compensation programs involving ungulates (deer, elk, moose, antelope, mountain goat, wood bison and bighorn sheep) included damage to cultivated crops (all 15 s/p), standing hay crops and pastures (5 s/p), stored hay (6 s/p), and damage to other property including fencing and irrigation equipment (8 s/p). Programs for lions, coyotes, and wolves (11 s/p) covered predation on livestock. Bear programs included livestock losses in 11 states/provinces, damage to bee-keeping equipment (12 s/p), crops (9 s/p), and other property (5 s/p). All 6 states or provinces with programs for damage caused by birds covered losses to cultivated crops. Programs in Wyoming and Wisconsin also covered bird damage to property.

The amount of money spent on compensation was highly variable among states and provinces and estimates provided by the survey sometimes included the cost of damage prevention materials and program administration. Weather conditions, changes in land use, and fluctuations in local wildlife population levels can cause yearly variation in damage claims. Other variables that impacted the amount of money spent on compensation programs included a ceiling on spending (which necessitated prorating the claims at the end of the year), the proportion of the property value reimbursed by the agency, substitution of damage prevention materials and labor for payments, and the issuance of hunting tags for sale by producers instead of cash payments. Expenditures in the U.S. for compensation ranged from $1,966 to $1,070,000 per state in 1993 while expenditures by Canadian provinces ranged from $10,000 to $1,200,000 ($ CAN). Some provinces and states reported restrictions on payments for damage below a certain threshold including $250 ($ CAN) for ungulate damage and $500 ($ CAN) for waterfowl damage in Saskatchewan, $100 ($ CAN) in Manitoba and the Yukon Territories, $100 in Minnesota, and $1,000 in Idaho.

Only Saskatchewan, Wyoming, Washington, West Virginia, and Wisconsin (R.R. Horton and S.R. Craven, Attitudes on shooting permit use for deer damage abatement in Wisconsin, 1995) reported conducting a review of participant attitudes toward their compensation programs.

Wisconsin and Saskatchewan reported conducting a review of taxpayer or general public attitudes toward existing compensation programs. In most instances, the review consisted of public hearings and personal comments to agencies when the program was due for renewal.

Program cancellations were reported by 6 states or provinces. Program cancellations in Massachusetts and Newfoundland were related to budget cutbacks. Claims of program exploitation also contributed to the cancellation of the Newfoundland program. Programs in Quebec and Nova Scotia were intended to last only until landowners could establish alternative management systems. The original "compensation only" program in Wisconsin was canceled in 1980 and replaced with a program that places an emphasis on providing damage prevention materials.

Programs loaning or sharing the cost of damage prevention supplies (assistance programs) were much more common than compensation programs with 7 provinces and 34 states providing some sort of assistance with nonlethal wildlife damage management tools. Assistance programs were more common in areas with compensation programs (80%) than in areas without compensation programs (58%). In 70% of the states with compensation and assistance programs, at least a portion of the assistance program was related to the damage covered by the compensation program. Programs providing frightening devices (for example, propane cannons and pyrotechnics) were the most common (31 s/p), followed by programs that provided or shared the cost of fencing materials (25 s/p). Other programs (<10 states/provinces each) included the loaning or paying all or a portion of the cost of repellents, lure crops, perforated PVC pipe for beaver impoundments, livestock guarding animals, or hiring herders to haze wildlife. The Saskatchewan crop insurance program pays establishment benefits to producers who can switch to crops less vulnerable to wildlife damage.

Many programs required producers to meet certain requirements prior to receiving compensation. In 6 states, landowners were required to provide public access to their lands for hunting before qualifying for assistance. Many programs had provisions that can exempt the state/province from paying producers using poor agricultural practices. Producers managing property to benefit from fee hunting for wildlife were excluded from some compensation programs. Producers receiving compensation for wildlife damage in Manitoba or the Yukon receive a list of recommendations for preventing additional damage. If they seek compensation a second time in a 5-year period, they are required to provide evidence that they have complied with the agency's recommendations for damage prevention.

DISCUSSION AND IMPLICATIONS

Nine of the 10 states reporting compensation programs for wildlife damage to crops in the 1957 survey by McDowell and Pillsbury (1959) had maintained or expanded these programs. New Hampshire was the only state to reduce its program, dropping coverage for "game" species, but adding a program for damage caused by black bear. Musgrave and Stein (1993) reported 21 states as providing "material support" for wildlife damage management, while in our survey, 34 states reported providing supplies or financial assistance for wildlife damage management materials. Five states listed by Musgrave and Stein (1993) as providing material support did not list programs in their response to our survey.

All states and provinces with wildlife compensation programs limit coverage to damage caused by a small number of wildlife species. Possible explanations for the inclusion of certain types of damage in compensation programs include compensating only for: (1) major problems where losses are so severe they threaten the profitability of agricultural producers; (2) common problems involving a large proportion of citizens; (3) situations where animals rights/animal welfare concerns restrict the use of management tools; (4) wildlife problems made more severe by management actions taken by governmental agencies; (5) recent problems where the wildlife populations and problems have changed substantially in the last few decades; and (6) problems caused by highly valued species, such as big game species and endangered species.

Compensation programs did not appear to be established in situations where wildlife caused the greatest threat to an agricultural producer's livelihood (hypothesis 1) because many compensation programs include species that cause minor losses but exclude other species that cause greater problems. For instance, some western states compensate for livestock losses to bears and mountain lions but not to coyotes; Minnesota compensates for elk damage but not deer damage; Utah compensates for ring-necked pheasant (Phasianus colchicus) damage to crops but not for damage by blackbirds (Agelaius spp.). Conover et al. (1995) estimated that approximately $22 million in annual timber damage is caused by flooding associated with beaver impoundments in the southeastern United States, but the only compensation program for beaver damage is for damage to crops and irrigation equipment in Utah.

Compensation programs also do not appear to be targeted at widespread problems involving a large number of citizens (hypothesis 2). Blackbirds, starlings (Sturnus vulgaris), raccoons (Procyon lotor), woodchucks (Marmota monax), mice/rats (Rodentia), and rabbits (Leporidae) cause widespread damage in North America (Conover 1994) but these species are not covered by compensation programs. Although 57% of the urban households surveyed by Conover et al. (1995) reported experiencing wildlife damage, there was not a compensation program for wildlife damage to residences.

It also seems unlikely that compensation programs are designed primarily as a humane and socially acceptable alternative to traditional, usually lethal, management tools (hypothesis 3). If the goal is to preserve species from pain and suffering, or death by humans, then the prevalence of game species in compensation programs is puzzling. If humane issues are the concern, why preserve a species from 1 person only so it can be killed during the hunting season?

The hypotheses that most compensation programs are designed to compensate for problems that are recent in origin (hypothesis 4), result from governmental actions (hypothesis 5), and are caused by highly valued species (hypothesis 6) are all valid explanations. These hypotheses are not mutually exclusive as more than one may apply to any given program. Most programs were established for species whose populations have increased in recent years due to the efforts of the state wildlife agency to increase populations of highly valued species (e.g., game species). Consequentially, compensation programs can be funded by taxes on user groups (hunting license revenues), general tax revenues, or funds from private organizations designed to help the species in question (Defenders of Wildlife and Great Bear Foundation).

Many courts have ruled that although the wildlife resource is owned by the public, governments are not liable for wildlife damage (Musgrave and Stein 1993). Why then do states/provinces voluntarily compensate for damages? Hypotheses 4-6 may provide rational reasons for doing so. When problems that limit agricultural productivity are of a long-standing nature, the limitation is incorporated into the price of the land. For instance, land with poor, shallow soils sells for less than land with deep fertile soils. In the same manner, land near a major blackbird roost should sell for less than land farther away. However, if the problem started since the current owner purchased the land, the threat of wildlife damage has not been incorporated into the land price. For these reasons, some wildlife agencies may feel a need to help farmers cope with new problems (hypothesis 4).

States have the responsibility of managing wildlife for the greater good of society, but in doing so, their actions may disadvantage some people. The problem is that only a small portion of the population may suffer the majority of the losses (Conover and Decker 1991, Conover 1994) while others receive the benefits. In instances when the state's own management activities have created or intensified a problem, the state may feel a sense of responsibility for the losses (hypothesis 5). Lastly, states may decide to compensate for wildlife damage for purely economic reasons (hypothesis 6). It may be a good investment of public funds to compensate farmers for damages by valuable animals, such as big-game species, rather than allowing farmers to kill depredating animals. This would be especially true if it is cheaper for the state to maintain high big-game populations by compensating farmers than to engage in other management practices such as habitat improvement projects.

Major problems with compensation programs are that they do not address the cause of the problem, and agencies can become trapped in a payment system for an indefinite period of time. To avoid this, many agencies helped landowners acquire resources needed for damage prevention as part of their compensation program. Allowing for the substitution of damage management materials and labor for cash payments insures that payments would only be granted if the participant had taken all reasonable precautions to prevent damage. The compensation program in Nova Scotia was designed to last only until all landowners had a reasonable opportunity to install damage prevention systems. Other states and provinces required producers to meet agency damage management recommendations before receiving compensation for >1 incident. Given the shifts and cancellations reported in the survey, compensation programs that included incentives or requirements for participants to institute damage prevention practices were the most likely to survive budgetary constraints. However, damage abatement requirements assumed that some effective reasonable damage prevention alternative exists. This is not always the case.

Compensation may not provide an incentive for producers to solve their own problem by improving management practices. Refusing payments for crops and livestock maintained using unsound agricultural practices is 1 option for addressing this issue. A controversial approach is to pay participants only a portion of the actual damage so that there is an incentive for agricultural producers to take action to prevent damage occurrence. The risk associated with this system is that it may also provide greater incentive for property owners to try otherwise unacceptable management techniques (USDA 1994). Participants using good management techniques may object because they receive partial payment for damages they cannot prevent. Partial payments may be more frustrating to farmers and ranchers than no payments, because the establishment of payment programs may be perceived as an acceptance of responsibility by the agency for wildlife damage. If this is true, landowners may wonder why an agency should only accept part of the responsibility for wildlife damage instead of paying for all the damage.

Potential difficulties with compensation programs include problems with agency awareness of all the programs available in their state, the amount of resources used in administering the program, and conflicts over damage assessment. Confusion over the existence of compensation programs could result in frustrated and impatient landowners trapped in red tape or shuffled between agencies. Managers administering compensation programs should take steps to insure that personnel working in related agencies are aware of the program and the procedures for receiving assistance.

Another difficulty is that a large portion of the funds available for a compensation program is used in administering the program and providing personnel to assess the extent of the damage. Contracting with an existing organization such as the Federal Crop Insurance adjusters who have personnel trained to assess crop damage may improve program efficiency. Delegating damage assessment to an agency with a history of addressing these issues may reduce accusations of unfair assessment to save agency funds. Conflicts over the level of damage assessment may still occur and most states/provinces with compensation programs had provisions for creating review committees to resolve conflicts over damage assessments.

Evidence of the appeal of compensation programs can be found in the willingness of private organizations like the Great Bear Foundation and Defenders of Wildlife to fund their own programs for species of particular interest to their members. However, compensation programs are not universally well received, making it important for agencies to establish a system for monitoring the attitudes of participants and the people providing funding for the program.

Many questions regarding the use of compensation programs have not been addressed. Given the studies reporting unfavorable public response to compensation programs (McIvor and Conover 1994, Kellert 1979), wildlife agencies should assess their wildlife compensation program to make sure it is worthwhile. Questions about any wildlife compensation program that need to be answered include how long should the compensation program last and is there a strategy on how to end it once it has begun? Does compensation really satisfy producers, or is it merely a "better-than-nothing" solution to problems? Producers rarely receive the actual value of the property damaged, but how much of a payment is needed to satisfy agricultural producers (100%, 50%, no payment but more technical assistance)? Does the compensation program improve goodwill for an agency within the community, increase agency moral, or decrease complaints? Given the cost of compensation programs, can these benefits be achieved using another system?

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Table 5.1. 1994 Compensation programs in the U.S. and Canada.

State or Province	Species involved	Agency
Alberta	waterfowl deer, pronghorn antelope, elk, moose	50:50 cost share[a] Provincial wildlife agency
Colorado	pronghorn antelope, elk, deer, black bear, mountain lion	State wildlife agency
Idaho	deer, elk, pronghorn antelope, moose, black bear, mountain lion gray wolf	State wildlife Defenders of Wildlife
Kentucky	coyote	State agriculture agency
Manitoba	waterfowl deer, elk, moose, wood bison, black bear	50:50 cost share[a] Provincial wildlife agency
Massachusetts	white-tailed deer, moose	State wildlife agency
Minnesota	gray wolf, elk	State agriculture agency
Montana	gray wolf grizzly bear	Defenders of Wildlife Great Bear Foundation
Nevada	deer, elk, pronghorn antelope	State wildlife agency
New Brunswick	coyote	Provincial agriculture agency
New Hampshire	black bear	State agriculture agency
North Carolina	red wolf	U.S. Fish and Wildl. Serv.
Ohio	coyote	State agriculture agency
Ontario	deer, coyotes, wolves	Provincial wildlife agency
Pennsylvania	coyote black bear	State agriculture agency State wildlife agency
Québec	snow goose (Chen caerulescens)[b]	Provincial wildlife agency

(table continues)

Saskatchewan	waterfowl white-tailed deer, mule deer, elk, pronghorn antelope, moose, bear	50:50 cost share [a] Provincial wildlife agency
Utah	deer, elk, moose, pronghorn antelope, ring-necked pheasant, beaver, waterfowl, black bear, mountain lion	State wildlife agency
Vermont	white-tailed deer, black bear	State wildlife agency
Virginia	white-tailed deer, black bear	Counties [c]
Washington	deer, elk	State wildlife agency
West Virginia	black bear	State wildlife agency
Wisconsin	white-tailed deer, goose, black bear	State wildlife agency
Wyoming	big game[d], trophy game and game birds gray wolf	State wildlife agency Defenders of Wildlife
Yukon	wood bison	Provincial wildlife agency

[a] 50:50 Cost share between provincial wildlife programs and Environment Canada for damage caused by migratory waterfowl.

[b] Cash program has subsequently been replaced with hunting permits which may be sold by landowners.

[c] Program only available for residents of counties choosing to require a wildlife damage stamp on hunting licenses. Only 4 counties were involved in the 1994-1995 hunting season.

[d] In Wyoming, "Big Game" includes elk, white-tailed deer and mule deer, moose, antelope, bighorn sheep and mountain goat; "Trophy Game" includes mountain lion, black bear and grizzly bear; and "Game Birds" includes ducks, geese turkeys, cranes, grouse, pheasant, etc.

CHAPTER 6

CONCLUSIONS

As used in my study, winter preventive aerial hunting was an effective and cost-efficient means of reducing confirmed and estimated sheep losses to coyote predation and the need for corrective summer predation management (SPM) on summer grazing pastures of the Intermountain West. Benefits associated with a reduction in SPM included time and resources saved on traveling to isolated allotments, reduced potential for conflict between recreational and ADC activities, and decreased risk to nontarget species from SPM tools like traps, snares, and M-44's. With aerial hunting, coyotes must be seen before they can be shot so risk to nontarget species is negligible. Although there were more hours of SPM in areas without aerial hunting, sheep losses to coyote predation were still higher in areas without aerial hunting than areas with it. This indicates that the amount of SPM available was not adequate to bring losses to the same level as a program using aerial hunting and SPM.

As with all wildlife damage management tools, there are costs associated with the use of aerial hunting. More coyotes are killed in areas with aerial hunting than in areas without aerial hunting, and aerial hunting did not significantly reduce the number of coyotes killed during SPM. These factors will be a problem for individuals concerned about the welfare of individual coyotes. Additionally, the coyotes that kill sheep cannot be identified and removed with aerial hunting, and a substantial portion of the coyotes killed may not be an immediate threat to livestock. Forty-five percent of the coyotes killed with aerial hunting were young-of-the-year and unlikely to produce pups during the subsequent breeding season (Knudsen 1976, Gantz 1990). However, data from Till and Knowlton (1983) indicated that the majority of the predation problem may be caused by adults with pups. In a study by Gantz (1990), territorial adult coyotes remained in their territories throughout the year. Therefore, aerial hunting may be especially valuable as a means of removing problem coyotes from allotments where the predation was not stopped with SPM before the sheep left the summer grazing area.

I presented 3 theories as to the effectiveness of aerial hunting: the population control hypothesis, the breeding pair hypothesis, and the problem coyote hypothesis. If the population control hypothesis was correct, aerial hunting significantly reduces sheep losses to coyote predation because it reduced local coyote populations. If this hypothesis was true, I predicted negative correlations between the extent and intensity of coyote removal, and sheep losses to coyote predation. I also anticipated lower sheep losses in areas where aerial hunting occurred later in the year (maximum impact on population, less time for immigration; Knowlton 1972, Stoddart et al. 1989). We did not observe any consistent relationships between the extent, intensity, or timing of aerial hunting and sheep losses to coyote predation. However, interactions between loss history for an area and aerial hunting effort may have confounded the data, making such a relationship difficult to determine. The helicopter crews knew where coyote predation was heaviest the year before and were willing to spend more time hunting in these "problem" allotments than in others. This hypothesis seems likely given that aerial hunting was conducted and directed by the local ADC specialists who had such knowledge. Furthermore, several informed us that this is their practice. Such a pattern should produce a positive correlation between the extent and intensity of aerial hunting and lamb losses and the need for SPM if aerial hunting was ineffective. However, our data showed the lack of either a positive or negative correlation. I interpret the lack of correlation between the extent and intensity of aerial hunting and lamb losses or the need for SPM to mean that aerial hunting successfully reduced coyote predation in problem allotments but did not completely eliminate loss. Hence, it can be inferred that by concentrating activity in these problem allotments, aerial hunting tends to reduce the inherent problems associated with them, making all allotments more or less equal in their potential for predator problems during the subsequent grazing season.

Although my data are not sufficient to disprove the population control hypothesis, data from 2 other studies also cast doubt on this hypothesis. Davison (1980) found no difference in coyote densities during spring or fall between an area that received little to no predator control and an area where coyote mortality from hunting was 50% higher in 1 year and 360% higher in another year. In an unpublished report by E.M. Gese (USDA Predator Ecology Center, pers. commun.), a Colorado coyote population in a 340 km^2 area was reduced approximately 50% by January aerial hunting (based on scent station indices and density estimates). Within 4-5 months, territory size, pack size, and density estimates had returned to pretreatment levels.

The breeding pair hypothesis is based on data provided by Till and Knowlton (1983) in which the majority of sheep losses appeared to be attributable to adult coyotes with pups. Unlike the population control hypothesis, the relationship between the extent and intensity of aerial hunting and sheep losses to coyote predation for the breeding pair theory is unclear. It seems likely that as the number of coyotes removed from an area increases, the greater the probability that the reproductively active adults have been removed. However, if the reproductively active adults are amongst the first to be removed from an area, additional removals will not necessarily result in a decrease in losses, and a correlation would not be observed. The answer may depend on which coyotes are vulnerable to aerial hunting. The greater the proportion of reproductively active adults in the samples captured by aerial hunting, the more unlikely relationship between extent and intensity of control and sheep losses is likely to be. In this study, 55% of the coyotes removed through aerial hunting were of age to form successful breeding pairs based on data from Knudsen (1976) and Gantz (1990). This ratio is higher than might be expected given the limited data previously available from Knowlton et al. (1985) and may be sufficiently high to make a relationship unlikely between the extent and intensity of aerial hunting and sheep losses or hours of SPM. I also anticipated that the age of coyotes removed during SPM should be lower in areas with consistent aerial hunting. This was not supported by my results although the data indicated a trend in this direction. My sample size was relatively small (38 coyotes) and additional data will be needed before this question can be answered.

The problem coyote hypothesis assumes that a coyote's vulnerability to SPM tools decreases with coyote age. Aerial hunting is believed to be effective because it removes coyotes that have learned to avoid other control tools. With this hypothesis, there does not need to be a relationship between the extent, intensity, or timing of aerial hunting and sheep loss to predation, but there should be a higher proportion of older coyotes in samples removed through aerial hunting than SPM. The difference in age of coyotes killed with aerial hunting and coyotes killed by shooting may be especially important in areas with high recreational use where ADC field specialists predominately use calling-and-shooting because it minimizes the risk to non-target species. I did not observe a significant difference between the age of coyotes captured in areas with and without consistent aerial hunting. However, the data indicated a trend in this direction, and it may be worthwhile to repeat this test with a larger sample. Although my data favor this hypothesis, the confounding factors in the study of correlations between the extent and intensity of aerial hunting make it impossible to completely dismiss the population control and breeding pair hypotheses.

The breeding pair and problem coyote hypotheses appear to be the 2 most likely theories on the effectiveness of aerial hunting as used in our study. These theories are not mutually exclusive, and it is possible that aerial hunting could remove more (problem) coyotes than SPM tools and still reduce density of breeding pairs. Studies assessing the impact of preventive aerial hunting on sheep losses during periods when coyotes are not feeding pups would provide valuable data on the breeding pair hypothesis. If preventive aerial hunting is effective at this time, then the impact of the tool cannot be totally dependent upon reducing the number of coyote pairs feeding pups.

A controlled study varying the intensity of aerial hunting and monitoring coyote density for the same sites over a period of consecutive years would distinguish density-dependent mechanisms (population control and breeding pair hypotheses) and the problem coyote hypothesis. There is some concern over the trend for the control sites in Chapter 1 to have higher losses than the treated sites during pretreatment years. A detailed study with varying intensity of aerial hunting as mentioned above might include years without treatment so that this concern could be addressed. Data on the relationship between hunting intensity and sheep losses will be valuable in refining the use of aerial hunting to receive maximum benefit from available hunting resources. This information would also aid producers in predicting loss reductions and determining if aerial hunting is appropriate for their area. Although our data indicated that aerial hunting has little or no long-term impact on coyote populations, information on the short-term impacts on population dynamics may help identify factors influencing predation rates. If predation rates are impacted by changes in population dynamics, then it may be possible to develop tools that achieve the same results with nonlethal mechanisms (e.g., immunocontraception could reduce the density of breeding pairs).

Financial compensation programs for wildlife damage were in place in 19 states and 7 Canadian provinces. Most programs were established for wildlife problems that were recent in origin, resulted from governmental actions, and/or were caused by highly valued species. From these criteria, it is not surprising that there is no compensation program for coyote damage in Utah, where coyotes have always been present and control tools are relatively unrestricted, but there are compensation programs for coyote damage in Pennslyvania, Kentucky, New Brunswick, and Ohio where coyotes are relatively recent arrivals. In contrast, bears and mountain lions have long been part of the Utah ecosystem, but state regulations restrict damage management options and these species are covered by compensation programs.

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APPENDIX

LIVESTOCK PRODUCERS PARTICIPATING IN THE STUDY

The assistance of the Utah, Idaho and Wyoming woolgrowers was essential for the success of this program. This list provides the names of the producers who maintained the work agreement with ADC, but thanks are also due to their families and the shepherds watching their sheep.

John Allen
Phil Allred
Larry Basterrechea
Bruce Barton
Roger Barton
Joe Broadbent
Jerry Chappel
Allen Dalley
Glen Deleeuw
Henry Etcheverry
Clark Fitzgerald
Bill Goring
Clair Halterman
Dean Hansen
Howard Hatch
Dennis Huntsaker
Charles Jenkins
Wade Jensen
Lorin Jones
Phyllis Laird
Kim Larsen
Carl Larson
Sherel Lister
Jack McCallester
Gary Madsen
Lamont Moon
Alan Ohlsen
Jerry Petersen
Tom Rich
Mike Simms
Jack Smith
Chris Sorensen
Dennis Stowell
Alan Stubbs
Scott Stubbs
Andy Taft
Dan Vacher
John Wintch

VITA

KIMBERLY KESSLER WAGNER

(February 1997)

CURRENT EMPLOYMENT

Research Wildlife Biologist (GS-11), USDA/APHIS/ADC National Wildlife Research Center, Olympia Field Station, 9701 Blomberg St. SW, Olympia WA 98512.

EDUCATION

Ph.D.	Wildlife Ecology	Utah State University	1997
M.S.	Wildlife Biology	University of Nebraska-Lincoln	1991
B.S.	Animal Ecology	Iowa State University	1989

Thesis: The impact of monofilament lines to selectively repel house sparrows from backyard feeding stations. Ron J. Johnson - Advisor.

Dissertation: Impact Preventive predation management, and evaluation using winter aerial coyote hunting in Utah and Idaho. Michael R. Conover - Advisor.

HONORS

-Associate Member Sigma Xi.

-Outstanding Student Presentation Award - 10 th Great Plains Wildlife Damage Control Conference,

-Outstanding Student Presentation Award - 12th Great Plains Wildlife Damage Control Conference.

-Best Poster Presentation - 53rd Midwest Fish and Wildlife Conference

-Berryman Fellowship - Jack H. Berryman Institute for Wildlife Damage Management, Department of Fisheries and Wildlife, Utah State University.

PROFESSIONAL EMPLOYMENT

Nov. 1996 - Present	Research Wildlife Biologist, USDA/APHIS/ADC/NWRC Olympia Research Station, 9701 Blomberg St. SW, Olympia WA 98512.
March 1992-Nov. 1996	Graduate Research Assistant, Department of Fisheries and Wildlife, Utah State University, Logan UT 84322-5210.
May 1990-Dec 1991	Graduate Research Assistant, Department of Forestry. Fisheries and Wildlife, University of Nebraska-Lincoln, Lincoln, NE 68583.
June-Aug. 1989	Staff Naturalist, Ames/ISU YMCA Day Camp, Iowa State University, Ames, IA 50011.
June-Aug. 1988	Naturalist Intern, Clayton County Conservation Board, Clayton County, IA 52043.
May-June 1988	Research Assistant, Department of Fisheries and Wildlife, University of Minnesota, St. Paul MN 55108.
May-Aug 1987	Naturalist Intern, Clayton County Conservation Board, Clayton County, IA 52043.

TEACHING EXPERIENCE

Sept.-Dec. 1994, 1995	Teaching Assistant, FW 510-Principles of Wildlife Damage Management, Department of Fisheries and Wildlife, Utah State University
March-June 1993	Teaching Assistant, FW 512-Problem Wildlife Management Techniques, Department of Fisheries and Wildlife, Utah State University.
Sept.-Dec. 1994	Teaching Assistant, FW 320-Animal Behavior, Department of Fisheries and Wildlife, Utah State University.

PUBLICATIONS

Conover, M. R., and K. K. Kessler. 1994. Diminished producer participation in an aversive

conditioning program to reduce coyote predation on sheep. Wildl. Soc. Bull. 22:229-233.

Conover, M. R., W. C. Pitt, K. K. Kessler, T. J. DuBow, and W. A. Sanborn. 1995. Review of human injuries, illnesses and economic losses caused by wildlife in the United States. Wildl. Soc. Bull. 23:407-414.

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Kessler, K. K., R. H. Schmidt and M. R. Conover. Submitted. Financial compensation programs for wildlife damage in North America. Wildl. Soc. Bull.

GRANTS AND RESEARCH SUPPORT

1992-96 Co-investigator: Impact of aerial hunting on sheep losses to coyote predation (U.S. Department of Agriculture $68,000).

1995-96 Co-investigator: Analysis of issues and problems in fish and wildlife management that confront U.S. fish and wildlife agencies. (International Association of Fish and Wildlife Agencies and the U.S. Fish and Wildlife Service $442,000).

1993-94 Berryman Fellowship (Jack H. Berryman Institute, Department of Fisheries and Wildlife, Utah State University $30,000)

SEMINARS AND PRESENTATIONS

1995 Financial Compensation Programs for Wildlife Damage in North America. (12th Great Plains Wildlife Damage Management Conference).

1995 Compensation for Wildlife Damage in North America. (Annual Meeting, Utah Chapter of the Wildlife Society).

1995 Management Techniques for Coyote Predation on Sheep. (Sheep Management and Wool Technology, ADVS 609, Utah State University).

1995 Use of Repellants and Aversive Agents in Wildlife Damage Management. (Problem Wildlife Management Techniques , FW 512, Utah State University).

1991 Wildlife Workshop Leader - Adams County School Camp, Adams County, Nebraska).

1991 Monofilament Lines to Selectively Repel House Sparrows from Backyard Feeding Stations (10th Great Plains Wildlife Damage Management Conference).

1991 Lines for House Sparrow Management at Backyard Feeders (Poster Presentation 53rd Midwest Fish and Wildlife Conference).

1991 Goodness Gracious Snakes Alive (Kirkman's Cove 4-H Day Camp, Tecumseh, Nebraska).

1991 Graduate Research in Wildlife Biology (Biology Careers Workshop, University of Nebraska-Lincoln).

1990 Lines for Bird Control at Backyard Feeders (Isaac Walton League, Lincoln, Nebraska).

PROFESSIONAL SERVICE AND MEMBERSHIPS

- Wildlife Society, National Animal Damage Control Association, Sigma Xi.

- Judge: Conservation and Wildlife exhibits Nebraska State Fair 1990, 1991, Cumming County Fair 1990, 1991, Lancaster County Fair 1990. Co-superintendent of Wildlife and Conservation Exhibits 1991 Nebraska State Fair.

- Representative to Graduate Student Senate, Department of Fisheries and Wildlife, Utah State University, Graduate Student Representative to Forestry, Fisheries and Wildlife Graduate Committee, University of Nebraska Lincoln.

OTHER SKILLS AND ACTIVITIES

-President Ames Chapter of the Society for Creative Anachronism..

-Publisher District Arts Newsletter for the Society for Creative Anachronism.

-District Arts Officer for the Idaho/Utah/Montana/Western Wyoming district of the Society for Creative Anachronism.