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Abstract: Cost-effectiveness of ADC's predator damage management efforts was identified as an issue of concern during preparation of an environmental assessment (EA) on predator damage management in southern Idaho. A specific benefit-cost analysis of ADC's efforts to protect sheep in southern Idaho was prepared to address this issue. This analysis involved a comparison of the difference between 1) the value of livestock losses sustained with a control program in place, plus the costs of implementing the program, and 2) the value of losses that could reasonably be expected without the program in place. This difference, divided by the cost to implement the program, provided the benefit-cost ratio. Additional data on the cost-effectiveness of increased helicopter aerial hunting of coyotes was reviewed from a study conducted during the early 1970s in Idaho, and from 3 years of helicopter aerial hunting in southeastern Idaho between 1994-1996. All of these comparisons suggested a positive benefit-cost ratio, ranging from about 3:1 to about 7:1. Factors influencing cost-effectiveness are discussed.

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Key Words: predator damage management, cost-effectiveness, aerial hunting

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The Animal and Plant Health Inspection Service, Animal Damage Control (APHIS-ADC) program in Idaho prepared an environmental assessment (EA) in 1996 to assess proposed alternatives and potential impacts of conducting a predator damage management program in the southern portion of the State. As part of this process, we solicited feedback from the public on issues or concerns that they wanted to see addressed in the EA. A wide variety of issues were identified, and this paper focuses on one of the most commonly expressed concerns, the cost-effectiveness of predator damage control efforts (USDA 1996).

Many critics of predator control efforts, including a number of the respondents that commented during our EA process, often make what they feel are logical comparisons regarding the cost effectiveness of predator control. One of these misguided comparisons involves looking at the cost of a control program, divided by the number of animals taken, and finding out that the average cost per animal taken may be several hundred dollars (O'Toole 1994). Some advocates of this viewpoint have suggested that it would make much more sense from an economic standpoint to simply start paying a bounty on coyotes, for instance, since more coyotes could be removed for less money in this manner. However, bounties simply encourage harvest of coyotes at times and in places when coyotes are easiest and cheapest to harvest. The goal in damage control efforts is not necessarily to remove maximum numbers of coyotes, but to resolve depredation problems. Many damage problems occur at times and in places where it is very difficult to remove the specific depredating coyotes. ADC's cost per coyote could be substantially reduced by ignoring those situations and instead concentrating on removing coyotes

where it could be accomplished more cheaply and effectively, but this would make no more sense than establishing a bounty system. Another common misconception expressed by some critics is that it would make more sense to simply compensate livestock producers for their losses, rather than implementing a damage control program. They typically come to this conclusion by comparing the cost of ADC's control efforts with the value of livestock losses confirmed by ADC. This logic fails to recognize that the losses confirmed by ADC constitute only a minor portion of the total losses, and that this level of loss is occurring *with a control program in place*. Without an effective control program, research suggests losses would likely be much higher (Nass 1977, 1980, Howard and Shaw 1978, Howard and Booth 1981, O'Gara et al. 1983).

METHODS

For purposes of the benefit-cost analysis in our EA, we used the logical and simplistic approach taken in an earlier analysis by Pearson and Caroline (1981). This approach involved a comparison of the difference between 1) the value of livestock losses sustained with a control program in place, plus the costs of implementing the program, and 2) the value of losses that could reasonably be expected without the program in place. This difference, divided by the cost to implement the program, provided the benefit-cost ratio.

We limited this analysis to quantifiable values, and did not include a number of values that would be difficult to measure. When sheep on rangelands are repeatedly harassed by predators, for example, they become extremely skittish. They do not disperse and feed normally, and therefore may not find the quality and quantity of feed that they would have if unstressed, resulting in lower lamb weights at the end of the grazing season. This is a form of predator damage, but it would be difficult to quantify. Wagner (1988) discussed additional examples of indirect predator damage, including increased labor costs to find sheep scattered by predators, and range damage related to the tighter herding required in response to the presence of predators. Our analysis likewise did not consider the value that some individuals might place on being able to see or hear coyotes more often when they visit Idaho rangelands, nor did it consider the unintentional harm or indirect benefits to other wildlife species.

We limited our benefit-cost analysis specifically to ADC's efforts to protect sheep in the analysis area during fiscal year (FY) 95 for two primary reasons. A critical part of the determination of benefit-cost is the estimation of losses that might reasonably be expected in the absence of a control program. Sheep are the only class of livestock for which studies have been specifically conducted to look at this issue. Also, FY 95 was the first full year for which the Idaho ADC program had data available from our computerized Management Information System (MIS). Availability of data from this reporting system allowed for close estimation of the amount of money spent specifically to protect sheep.

A total of four research studies were conducted in the early 1970s to assess the level of predator damage that could occur in the absence of predator control (Henne 1975, Munoz 1977, McAdoo and Klebenow 1978, and Delorenzo and Howard 1976). The results of these four studies were reviewed in ADC's programmatic Environmental Impact Statement (EIS) (USDA 1994) to determine what level of predation might reasonably be expected in the absence of a control program. Based on this review, the unweighted average rate of loss to coyote predation cited in USDA (1994) was 4.5% for sheep and 17% for lambs. For purposes of our analysis, we chose to be more conservative and assumed that loss rates for sheep and lambs could reasonably be expected to be 4% and 15% in the absence of a control program.

We relied on data collected by the Idaho Agricultural Statistics Service (IASS 1996) to assess the magnitude of sheep losses due to predation, with a control program in place. IASS conducts a survey of Idaho sheep producers every year in January, and collects information not only on producers' inventory, but also on the amount of death and theft loss incurred during the previous year. Although some of the commenters during our EA process felt that producers may have a tendency to overestimate

their predation losses, there is strong evidence to support the reliability of producers' estimates. Average losses attributed to predation by Idaho sheep producers between 1993-1995 amounted to about 35% of the total reported death loss (IASS 1996). However, through intensive monitoring conducted during a study on three typical range sheep operations in southern Idaho, Nass (1977) found that predation was actually responsible for 56% of the total lamb losses. Pearson (1986) reported on several studies that indicated little or no bias occurred in ranchers' reporting of losses, and Wywialowski (1994) likewise found that livestock producers' estimates of wildlife-caused damage were consistent with estimates based on studies and surveys of predation rates.

IASS (1996) county-by-county sheep inventory data suggested that approximately 94% of the sheep numbers in the state were contained in our southern Idaho analysis area in 1995. Applying this percentage to their statewide predator death loss figures suggested that 3,348 adult sheep and 11,718 lambs were lost due to predation in the analysis area in 1995. Average value per head, based on beginning and end of year values for sheep and lambs was $92.50. Estimated total value of the losses actually sustained with a control program in place then equaled $1,393,605.

Total cost of efforts to protect sheep in the analysis area in FY 95 was determined through a careful review and tabulation of MIS data. District Supervisors and their field employees reviewed MIS summary reports for FY 95 to determine how many direct control and technical assistance hours had been spent conducting work to protect sheep in their districts and in the analysis area. Approximately three fourths of the total field effort in Idaho is carried out within the southern Idaho analysis area. After determining that 75% of the total direct control hours carried out in the analysis area were spent protecting sheep, this same proportion was applied to relevant "task" hours recorded in MIS reports, so that a pro-rated share of time spent attending work plan meetings, preparing weekly reports, working on equipment, etc., was included as part of the effort to protect sheep.

All of the hours worked by the entire State office staff were also pro-rated and included as sheep protection efforts. Review of MIS aerial hunting summary reports also allowed us to determine that 100% of the helicopter aerial hunting hours and 57% of the fixed wing aerial hunting hours were flown for protection of sheep. These percentages were applied to all the ferry time recorded on the MIS aerial hunting summaries to include the appropriate pro-rated share of this time as well. Total cost of the program to protect sheep in the southern Idaho analysis area during FY 95, including salaries and benefits for field, supervisory, and administrative staff, vehicle and aircraft expenses, supplies and equipment, came to a total of $664,261.

Using sheep and lamb inventory data and extrapolated predation loss figures from IASS (1996), the 3,348 sheep and 11,718 lambs lost to predation represent 1.5% and 4.9% predation losses, respectively. If we make the conservative assumption that losses in the absence of control would be 4% of the sheep and 15% of the lambs, then losses would have been an estimated 9,114 sheep and 35,712 lambs. At the IASS (1996) average value of $92.50/head, the total value of these losses would have been $4,146,405. The difference between 1) the value of the actual 1995 losses, plus the cost of the control program, and 2) the value of what losses could reasonably be expected to be in the absence of a control program, divided by 3) the cost of the program, equals 3.14. The benefit-cost ratio for the ADC program's efforts to protect sheep in southern Idaho in FY 95 was approximately 3:1.

Table 1. 1995 actual and projected predation losses for sheep in southern Idaho.

	Actual losses with ADC	(% Predation)	Projected losses without ADC	(% Predation)
Adult Sheep	3,348	(1.5%)	9,114.00	(4%)
Lambs	11,718	(4.9%)	35,712	(15%)
Total Sheep & Lambs	15,066		44,826	
Total Value (@ $92.50/head)	$1,393,605		$4,146,405	

Table 2. Benefit-cost ratio for efforts to protect sheep in southern Idaho.

(a) Value of actual '95 losses	$1,393,605
(b) Cost of the control program	$664,261
(c) Sum of *a* + *b*	$2,057,866
(d) Value of losses that could reasonably be expected in the absence of a control program	$4,146,405
(e) Difference between *c* and *d* *(value of avoided losses)*	$2,088,539
$2,088,539 / $664,261 = 3.14 *(value of avoided losses ÷ cost of the control program= benefit)*	

A slightly different approach for determining cost-effectiveness of one particular control method was taken during further analysis in our EA. In this approach, instead of assuming a specific level of increased loss in the absence of a control program, we used the actual losses sustained with a specific level of control in place, and compared that to the reduced level of losses sustained when control efforts were increased. We first reviewed data from a study documented by Packham (1973) in an unpublished report, wherein the effectiveness of helicopter aerial hunting of coyotes to protect sheep in southern Idaho was assessed from 1972-1973. This study was one of several undertaken in the western U.S. shortly after the use of predator toxicants was banned by Federal Executive Order in 1972. The study documented the extent and cost of control efforts, coyotes taken, and lambs lost to coyote predation on 6 spring sheep ranges in southern Idaho. All 6 of the study areas received control in the form of trapping, calling and shooting, and denning. Four of the 6 areas received additional control in the form of helicopter aerial hunting. In the 4 areas that received aerial hunting, the aerial hunting effort during the second year of the study was substantially increased over the effort expended during the first year. We looked at the difference between the numbers of lambs killed by coyotes during the two years, and compared this to the increased costs for control. The figures shown in Table 3 represent the cumulative totals for the 4 aerial hunting areas combined.

Table 3. Combined totals for aerial hunting effort and predation losses on four study areas[a], and resultant benefit from increased effort.

	Aerial Control Cost	Coyotes Killed	Lambs Killed by Coyotes
1972	$2,574	32	1,092
1973	$8,079	111	376
Extra dollars spent = $5,505		Avoided losses = 716	
Lamb prices averaged $40/head			
$40 x 716 lambs = $28,600 in losses avoided			
$28,600 / $5,505 = 5.19			
(value of avoided losses ÷ cost of additional control = benefit)			

[a]From Packham (1973)

In the four areas receiving aerial hunting, coyote predation on lambs decreased from 1.9% in 1972 to 0.6% in 1973, while in the two areas where no aerial control was conducted, coyote predation on lambs increased from 3.8% in 1972 to 5.0% in 1973. The ground control effort on the four aerial hunting areas was essentially the same during the two years, but the ground control effort on the two non-aerial hunting areas was increased from 32 to 59 man days during the second year. Numbers of sheep and lambs present stayed essentially the same on all areas during both years. Catch-per-unit-effort data from ADC's fixed-wing aerial hunting efforts across southern Idaho suggested that coyote populations were increasing during this period. The number of coyotes taken per hour of fixed-wing aerial hunting increased from .9/hr. in 1963 to 3.5/hr. in 1973, and anecdotal information from the aircraft pilots at that time indicated a noticeable increase in coyote numbers from 1970-1974. Given these factors, it seems reasonable to assume that if aerial hunting had not been increased in 1973, coyote predation on lambs probably would have been at least as great as it was in 1972. Although this comparison involved only 2 years, the data suggests that for every additional dollar spent on helicopter work during the second year, an average of $5.19 worth of lambs were saved.

We similarly assessed cost-effectiveness of increased helicopter aerial hunting efforts to protect sheep on the Caribou National Forest in southeastern Idaho from 1994-1996. This is an area where varying levels of helicopter aerial hunting have been carried out every winter since the mid-1970s to protect sheep present on forest grazing allotments during the following summer months. Federal monies available for conducting winter helicopter work have declined in recent years, and the amount spent in 1994 was deemed inadequate by sheep grazing permittees. They responded by contributing additional dollars for helicopter work in 1995 and again in 1996. Table 4 shows the numbers of coyotes taken during ADC's aerial hunting efforts, the total cost for this control, numbers of sheep and lambs subsequently present in the control area, and the permittee-reported coyote losses for the years 1994-1996. Summer time ground control efforts were similar during these 3 years. Conditions were judged to be somewhat more conducive to effective aerial hunting in 1995 and 1996 than they were in 1994 (i.e., better snow conditions may have allowed finding more coyotes), but we could not definitively quantify the effect this may have had.

Table 4. Aerial hunting effort and predation losses for cooperating sheep producers on the Caribou National Forest.

Fiscal Year	Coyotes Taken by Aerial Hunting	Aerial Control Cost	Sheep & Lambs in Control Area	Permittee Reported Losses	
1994	57	$9,355	51,600	2,024	(3.9%)
1995	137	$16,193	55,700	967	(1.7%)
1996	296	$18,158	52,600	896	(1.7%)

For purposes of this analysis, we assumed that at least some portion of the reduction in losses could be attributed not just to the increased aerial hunting effort in 1995 and 1996, but also to an assumed increase in relative effectiveness in 1995 and 1996 due to better aerial hunting conditions. Although we can only speculate about the degree of this effect, we estimated that the percent predation loss would have been as much as 25% lower in 1994 if there had been a similar level of relative effectiveness. Under this assumption, losses in 1994 would have only been about 2.9% rather than 3.9%, for a total of only 1,496 sheep and lambs killed instead of the reported 2,024. Tables 5 and 6 show comparisons of this assumed lower predation loss rate for 1994 with the actual loss data from 1995 and 1996. These comparisons suggest that for every additional dollar spent for aerial control in 1995, about $7.19 worth of sheep and lambs were saved, and about $6.34 worth of sheep and lambs were saved for every additional dollar spent in 1996.

Table 5. Comparison of aerial hunting effort and predation losses for 1994 and 1995, and resultant benefit from increased effort in 1995.

	Aerial Control Cost	Coyotes Taken	Sheep & Lambs Killed by Coyotes	
1994	$9,355	57	1,496	(2.9%)[a]
1995	$16,193	137	967	(1.7%)
Extra dollars spent = $6,838			Avoided losses = 529	
Sheep & lamb 3-yr avg. value of $93/head (IASS 1996)				
$93 x 529 = $49,197 in losses avoided				
$49,197 / $6,838 = 7.19				
(value of avoided losses ÷ cost of additional control = benefit)				

[a]Adjusted down from the actual 3.9% loss level based on the assumption that the percent predation loss would have been as much as 25% lower in ‘94 if there had been a similar level of relative effectiveness per unit of effort during both years.

Table 6. Comparison of aerial hunting effort and predation losses for 1994 and 1996, and resultant benefit from increased effort in 1996.

	Aerial Control Cost	Coyotes Taken	Sheep & Lambs Killed by Coyotes	
1994	$9,355	57	1,496	(2.9%)[a]
1996	$18,158	296	896	(1.7%)
Extra dollars spent = $8,803			Avoided losses = 600	
Sheep & lamb prices averaged $93/head				
$93 x 600 = $55,800 in losses avoided				
$55,800 / $8,803 = 6.34				
(value of avoided losses ÷ cost of additional control = benefit)				

[a]Adjusted down from the actual 3.9% loss level based on the assumption that the percent predation loss would have been as much as 25% lower in '94 if there had been a similar level of relative effectiveness per unit of effort during both years.

DISCUSSION

We believe the 3:1 benefit-cost ratio calculated during preparation of our EA represents a conservative estimate for several reasons. As previously noted, we chose to use a more conservative estimate of losses that could reasonably be expected in the absence of control than did the analysis in ADC's programmatic EIS. Also, unlike some other economic analyses (Thompson 1976, USDI 1978, USDA 1994) our analysis did not consider the economic impact of predation on other segments of society, such as manufacturers and consumers. The estimate of ADC expenses for protecting sheep in the analysis area has probably been overstated, which would also contribute to a reduced benefit-cost ratio. After determining the average portion of our field employees time spent protecting sheep, we simply applied this same factor to the time of the entire State office staff and considered that amount of time as support for efforts to protect sheep. In actuality, the State Director's time is occupied by a much greater variety of tasks than this assumption suggests, so the estimated cost is slightly inflated.

A benefit-cost analysis of ADC activities as conducted back in the decades of widespread toxicant use would likely show a much higher benefit per unit cost than predator damage management programs as currently practiced. Computer simulation modeling of various coyote control options suggests that, in general, control programs employing toxicants provide the greatest net economic benefits (Gum et al. 1978). Cain et al. (1972) noted that toxicants were "conspicuously effective and economical" for predator control, but that they were also generally less selective. Although toxicants were cheap and very effective at keeping predator numbers and predation losses low, there were strong societal concerns about some of the environmental impacts of their use. Our social value system has essentially established limits on how cost-effectively wildlife damage management can be conducted. As restrictions on use of damage management methods increase, cost-effectiveness is reduced (Connolly 1981).

Cost-effectiveness of various control strategies can vary greatly depending on a variety of factors. Effectiveness of aerial hunting efforts, for instance, can vary with the presence or absence of fresh snow cover, as well as use of a ground crew to locate coyotes, prior use of draw stations to attract coyotes, and other factors. The benefit-cost ratios discussed in this paper fall generally within the range of those discussed by other authors. USDA (1994) suggested a 2.4:1 benefit:cost ratio for predator control efforts to protect sheep in the western U.S., and Wagner (1997) suggested a 2.6:1 benefit-cost ratio for helicopter aerial hunting efforts to protect sheep in Utah and Idaho. Thompson (1976) suggested a 3.9:1 benefit-cost ratio with

trapping as the primary control tool in California, and Pearson and Caroline (1981) estimated a benefit-cost ratio of 4.5:1 for predator control during a one-year analysis period in Texas. Connolly (1981), suggested a 7:1 benefit-cost ratio for government predator control efforts in the western U.S. Predator control efforts may not be cost-effective in all circumstances, but the reasons for this may involve the need to address social or environmental concerns that are difficult to quantify in economic terms.

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