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An Economic Analysis of Predator Management in Wyoming

First Year Results Report

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Section I: Wyoming Sheep and Lamb Predation Trends: 1965 to 2006

Introduction

Wyoming sheep producers have experienced predation on their flocks since domestic sheep were brought to Wyoming in the 19th century. Early efforts to control predators were initiated by individual ranchers or small local groups. The first federal involvement in wildlife damage control in the United States occurred in 1885. By 1915, Congress was appropriating funds for federal predator control operations directed at wolves and coyotes. In 1931, Congress passed the Animal Damage Control Act authorizing the control of injurious animals, which is still in effect today. The State of Wyoming has also been actively involved in predator management during most of its history. Today, USDA's Wildlife Services, the Wyoming Animal Damage Management Board, County Predator Management Boards, and individual livestock producers work cooperatively to manage predators in Wyoming.

Methods

Data on predation in the early years of settlement is scarce. While some information is available regarding the number of predators harvested, there does not appear to be any coordinated effort to gather data on livestock losses. In more recent times, the Wyoming Crop and Livestock Reporting Service, which later became part of the National Agricultural Statistics Service (NASS), has reported estimates of annual predation of sheep and lambs in Wyoming. By examining available publications of the annual Wyoming Agricultural Statistics publication, we assembled a data base of sheep and lamb predation for a 42 year period from 1965 to 2006. This data base includes number of sheep and lamb losses, the market value of the losses, and the type of predator responsible for the losses. Some have questioned the accuracy of the NASS livestock predation estimates because the data is based on NASS interviews of livestock producers; however, the United States General Accounting Office (2001) has determined that available evidence indicates that the NASS estimates are reliable.

The following is a discussion of the trends in sheep and lamb predation in Wyoming from 1965 to 2006. This discussion includes the number of head lost to predators, the market value of the livestock loss, and the type of predator responsible for the loss. The market value of the livestock losses have been adjusted for inflation to 2005 dollars based on the national Producer Price Index. NASS estimates of the lamb crop and breeding sheep inventory for Wyoming were used to compare the percent of lamb and sheep losses to predators between different years.

Results

Figure 1 illustrates the number of head of sheep and lambs lost to predators in Wyoming between 1965 and 2006. Over the 42 year time frame, a total of nearly 3.3 million head of sheep and lambs were lost to predators in Wyoming. Approximately 80 percent of the losses were lambs with the balance being adult sheep. This represents a ratio of four

lambs for every one sheep lost. The average number of head lost per year was approximately 78,000. There is also substantial annual variability in the losses to predators. The maximum annual change was approximately 43 percent with a standard deviation of approximately 17 percent. The peak years for sheep and lamb predation in Wyoming were 1973 and 1974 when the total loss approached 140,000 head. Although subject to substantial annual variability, after 1974 there was a general decline in predation losses until 1989 when predation losses for sheep and lambs were slightly more than 47,000. Between 1989 and 1993 predation losses for sheep and lambs more than doubled, approaching 100,000 head in both 1993 and 1994. Since 1994 there has been a general decline in predation losses for sheep and lambs. In 2006 the reported loss was 24,600 head.

Figure 2 illustrates the market value of sheep and lambs lost to predators in Wyoming between 1965 and 2006. Over the 42 year time frame, the market value of sheep and lambs that were lost to predators was nearly $185.5 million in 2005 dollars (Table 2). The average annual loss was $4.4 million although again there was a general downward trend in the market value of losses after 1974. Not surprisingly, the market value of sheep and lamb losses tend to follow the trend in number of head lost. The peak year in terms of market value loss was 1973 when the loss exceeded $9 million. In 2006 the market value of the loss was $1.8 million.

One of the reasons for the general decline in sheep and lamb predation between 1974 and 2006 was the overall decline in the size of the sheep inventory in the state during this time period. As shown in Figure 3, the breeding sheep inventory in Wyoming declined steadily from nearly 2 million head in 1965 to 350,000 head in 2006, with most of the decrease occurring before 1980. The decline in sheep numbers suggests a decline in the opportunities for predation to occur within the state.

In order to account for the effects of a declining sheep inventory on predation in Wyoming, predation loss as a percent of the lamb crop and breeding sheep inventory were calculated. Estimates of both the annual lamb crop and the breeding sheep inventory were obtained from various issues of the Wyoming Agricultural Statistics. The results of the percentage loss calculations are summarized in Figures 4 and 5.

For lambs (Figure 4), predator loss more than doubled from 5 to 6 percent of the lamb crop between 1965 and 1968 to 12 percent in 1974. From 1974 to 1991, although the annual percentage loss varied substantially, the average loss was about 10 percent. In 1992, predation of lambs began to increase, peaking at 16 percent in 1993 and 1994. After 1994, the lamb loss averaged about 12 percent between 1996 and 2002, falling to 9 percent in 2003 and 2004, and 7 percent in 2005 and 2006. Overall the lamb loss to predators in 2006 was about 30 percent higher than it was in 1965 (7.0 percent vs. 5.5 percent).

The pattern of predator losses for adult sheep are similar to lambs, although at a much lower rate (Figure 5). The peak year was 1976 when sheep losses to predators were 2.6 percent of the Wyoming breeding sheep inventory. In 1994 sheep predation again peaked,

this time at 2.4 percent. In 2006 the sheep loss to predators was a third less than in 1965 (0.9 percent vs. 1.4 percent).

The NASS data also provides estimates of predation by selected predator species, including coyotes, eagles, bears, and mountain lions. Coyotes are the dominate predator of domestic sheep and lambs in Wyoming representing between 65 and 80 percent of the losses from 1965 and 2006 (Figure 6). Between 1965 and 1969 the percent of the total loss from coyotes was approximately 70 percent. This percent increased to the 70 to 80 percent range between 1970 and 1996. However, since 1996 the percent of predator loss attributed to coyotes has again declined to below 70 percent.

Between 1965 and 1993 eagles accounted for from 5 to 10 percent of sheep and lamb losses to predators in Wyoming (Figure 7). This rate increased to the 10 to 15 percent range between 1994 and 2004 before dropping back to the 5 to 10 percent range in 2005 and 2006.

Figure 8 summarizes the relative importance of bears as sheep and lamb predators. After increasing rapidly as a percent of total predation from 1965 to 1969, bear predation declined to less than three percent of total predator losses between 1971 and 2002. However, since 2002 bear predation has increased to over 5 percent in most years.

Figure 9 summarizes the relative importance of mountain lions as sheep and lamb predators. NASS only started estimating predator losses associated with mountain lions in 1986. As the figure shows, the percent of predator losses from mountain lions declined from 1986-1988 levels for several years, but we are currently seeing an increase in the percent of predator losses from mountain lions.

Summary and Conclusions

Historically, predator losses represent a significant cost to Wyoming sheep producers. Between 1965 and 2006 a total of nearly 3.3 million head of lambs and sheep in Wyoming were lost to predators. This 3.3 million head loss had a market value, in inflation adjusted dollars, of $185 million. Although the breeding sheep inventory continues to decline in Wyoming, predators remain a concern for sheep producers in the state. In 1993, it is estimated that more than 16 percent of the state's lamb crop was lost to predators. This was the highest percentage loss of any year between 1965 and 2006. Since these losses are not evenly distributed across all producers, certain individual producers probably suffered the majority of these losses. This may cause significant financial difficulties for these individual operations. In fact, these high levels of predator losses correspond with significant decreases in the breeding sheep inventory during this time period. In recent years the declines in the percent loss to predators has been more than double the percent decline in sheep numbers which may indicate that increased efforts to manage predators in Wyoming are effective. Lastly, coyotes remain the primary predator for sheep and lambs in Wyoming accounting for 65 to 80 percent of the total loss. This analysis has only considered predator losses in terms of sheep and lambs.

Other losses such as cattle and wildlife would need to be quantified in order to get a complete picture of the predator situation in Wyoming.

Figure 1.
Wyoming Sheep & Lamb Losses to Predators,
1965-2006

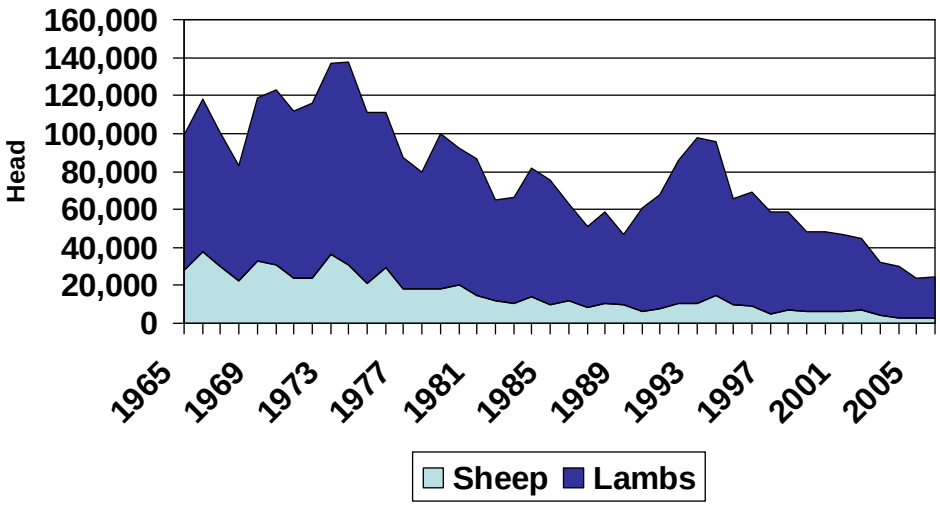


Figure 2.
Value of Wyoming Sheep & Lamb Losses to Predators,
1965-2006 (Adjusted for Inflation)

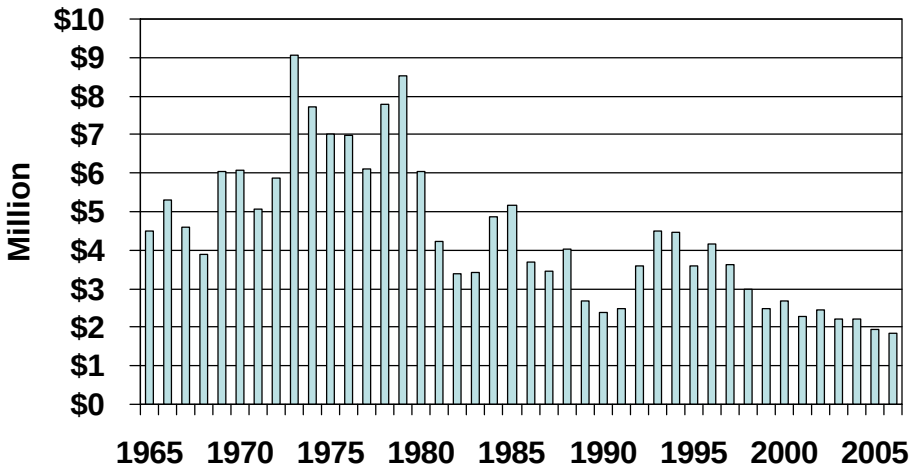


Figure 3.
Wyoming Breeding Sheep Inventory, 1965-2006

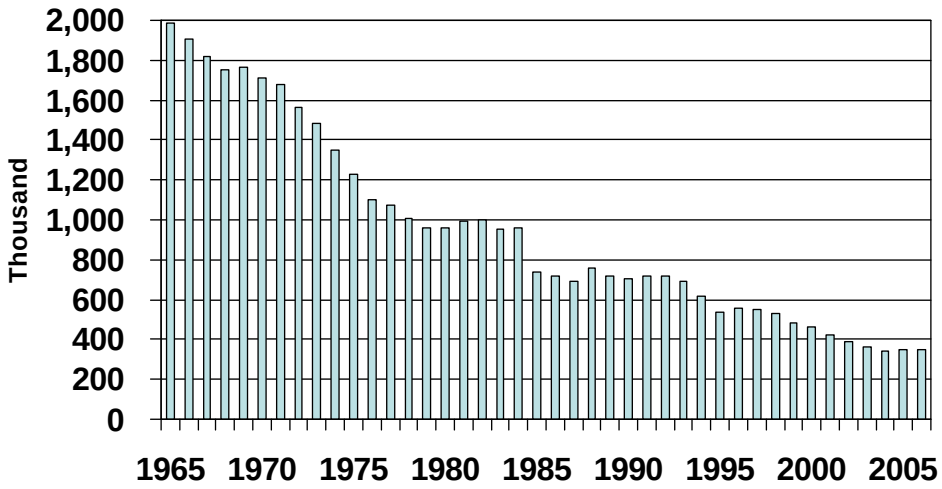


Figure 4.
Percent of Lambs Lost to Predators in Wyoming, 1965-2006

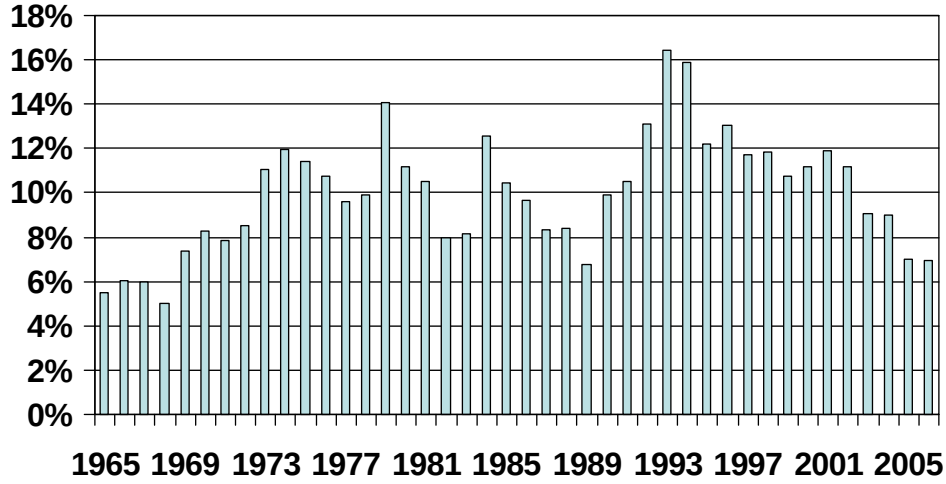


Figure 5.
Percent of Sheep Lost to Predators in Wyoming, 1965-2006

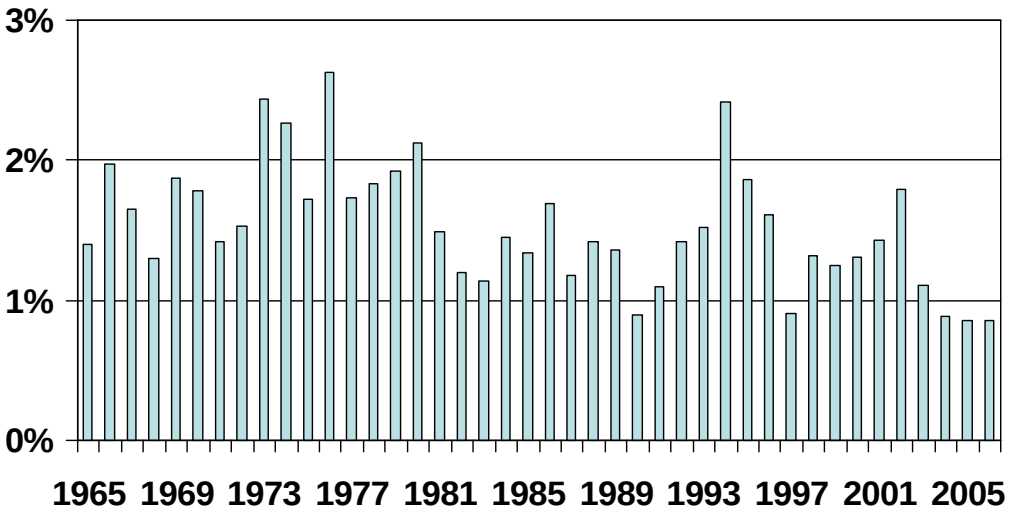


Figure 6.
Coyotes as a Percent of Predator Losses for Sheep and Lambs in Wyoming, 1965-2006

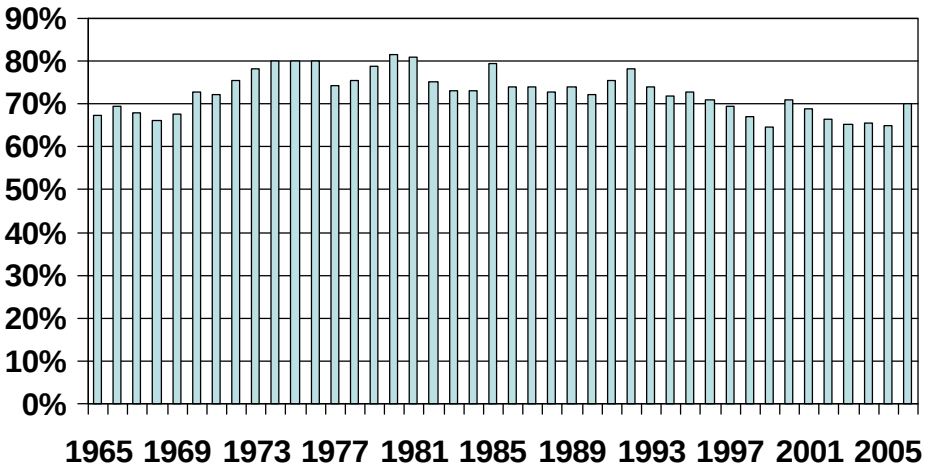


Figure 7.
Eagles as a Percent of Predator Losses for Sheep and Lambs in Wyoming, 1965-2006

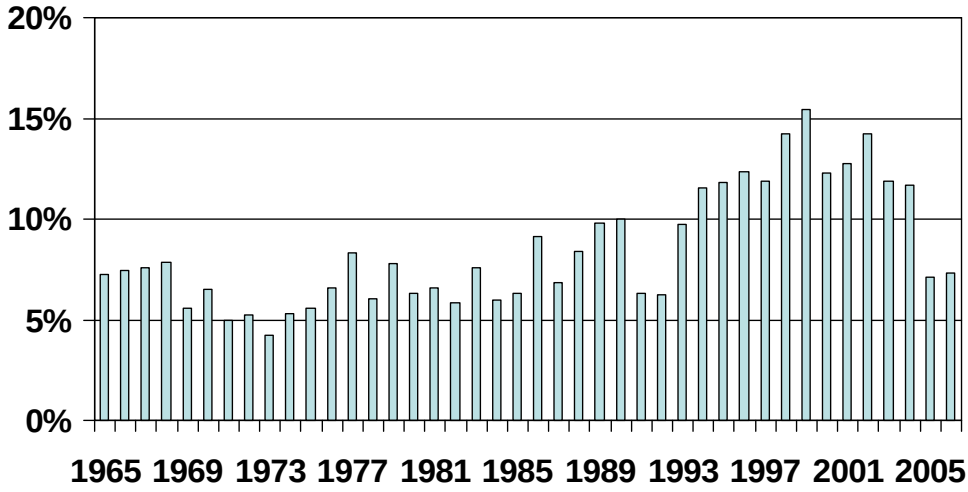


Figure 8.
Bears as a Percent of Predator Losses for Sheep and Lambs in Wyoming, 1965-2006

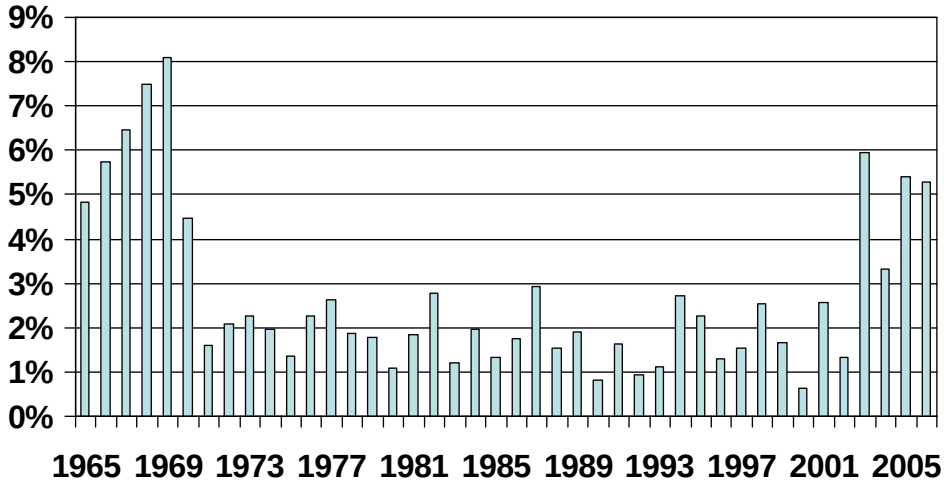
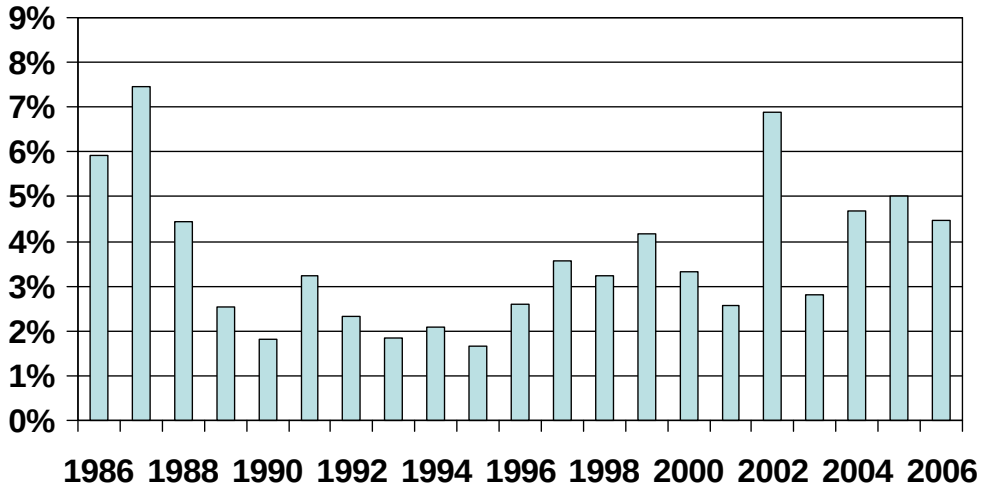


Figure 9.
Mountain Lions as a Percent of Predator Losses for Sheep and Lambs in Wyoming, 1986-2006



Section II: Preliminary Estimates of the Economic Benefits and Costs of Predator Management in Wyoming

Introduction

Predator damage represents a significant cost to Wyoming agricultural producers. The Wyoming Field Office of the National Agricultural Statistics Service (NASS) estimates that the agricultural industry in Wyoming lost 4,000 cattle and calves and 24,000 sheep and lambs to all predators during 2005 (NASS, 2006). NASS estimates that the market value of this lost livestock was nearly $4.0 million. Predators also affect wildlife populations. Shwiff and Merrell (2004) found that 800 antelope were saved through predator management of coyotes during a two year period in a 367 square mile area of South Central Wyoming. They estimate that the annual value of the antelope saved ranged from $200,159 to nearly $4.5 million depending on the estimated value used for antelope. The wide range in the estimated value of antelope saved resulted from the authors' use of four different values for individual antelope ($400, $1,500, $3,000, and $10,000). This range in values suggests considerable uncertainty regarding the valuation of antelope.

The purpose of this report is to present preliminary estimates of the economic benefits and costs of predator management in Wyoming. The analysis is limited to the economic benefits to livestock production since estimates of these benefits were more readily available than those for wildlife. The estimated livestock benefits are compared with the costs associated with predator management in the state to determine net benefits and the benefit-cost ratio of predator management in Wyoming.

Results of the analysis indicate that the estimated total economic benefits of predator management to livestock production in Wyoming for 2005 ranged from $9.5 to $13.9 million. The estimated costs of predator management in Wyoming for 2005 were $6.0 million. These results indicate an estimated net economic benefit from predator management to livestock production in Wyoming for 2005 of $3.5 to $7.9 million and a benefit-cost ratio of 1.6 to 2.3.

The issue of benefits to wildlife will be considered in subsequent analysis. This report is part of a larger project being conducted for the Wyoming Animal Damage Management Board by the Department of Agricultural and Applied Economics, College of Agriculture, University of Wyoming. More detailed reports on the economics of predator management in Wyoming will be forthcoming as the project progresses.

This analysis was based on the year 2005 since that was the most recent year when all the necessary data were available and because it was immediately prior to the State of Wyoming significantly increasing funding for predator management. Thus this analysis represents a baseline that should contribute to the evaluation of the future effectiveness of the predator management program in Wyoming.

Methods

The benefits of predator management are difficult to determine because it requires estimation of the loss that is prevented by the management actions. Thus, estimates of the death loss with and without predator management are needed. Since some form of predator management is conducted in most western states, information on death loss *with* management is readily available, however because of these management efforts information on the potential death loss *without* predator management are difficult to obtain. For this analysis, estimates from Bodenchuk (2000) on death loss with and without predator management were used to estimate economic benefits. Bodenchuk estimated death loss with predation management based on a NASS survey of livestock producers who used USDA-APHIS Wildlife Services programs to manage predation (NASS, 1999). He then used a meta-analysis of research on predator losses in the absence of predation management programs in Montana, California, and New Mexico to estimate death loss without predation management. The Bodenchuk article was utilized in the analysis because it considered multiple studies and included studies in regions where livestock production is similar to that found in Wyoming.

Two methods were used to estimate the benefits of predator management. The first (Method #1) was based on the predator losses reported by Bodenchuk with and without predator management. Because the total predation death loss for Wyoming estimated by this method slightly exceeded the predation death loss estimates for Wyoming in 2005, an alternative method of estimating total benefits from predator management was calculated for comparison purposes. In this second approach (Method #2) the difference in death loss with and without predator management from Bodenchuk was applied to the observed death loss reported for Wyoming in 2005.

The costs of predator management are easier to estimate than benefits because some form of predator management is conducted in most western states, and information on the costs of such programs is readily available. For this analysis three categories of predator management costs were considered, including: 1) expenditures by the Wyoming Office of Wildlife Services, 2) expenditure by County Predator Management Boards, and 3) expenditures by livestock producers. These cost estimates were then compared with the benefits estimates to determine the net benefits and the benefit cost ratio for predator management in Wyoming. Due to the difficulty in estimating the potential death loss of livestock without predator management, a breakeven analysis was conducted to determine the minimum amount of a predation management benefits needed for the management effort to be cost effective.

Results

Table 1 summarizes Bodenchuk's estimates of death loss with and without predator management. With predator management estimated death losses ranged from 0.8 percent for calves to 6.0 percent for lambs. However, without predator management death losses are estimated to range from 3.0 percent for calves to 17.5 percent for lambs.

Bodenchuk's analysis suggests that death loss rates without predator management are three or more times higher than those with predator management.

In order to determine if the death loss rates from Bodenchuk are applicable to Wyoming, his death loss with predator management estimates were compared with the implied death loss estimates for 2005 derived from the Wyoming Agricultural Statistics (NASS, 2006). Table 2 illustrates how these two sets of death loss numbers compare. The two sets of estimates are generally comparable with only a few percentage point differences between the two. Overall, the total death loss rate is very comparable (2.1 percent vs. 2.0 percent). Thus Bodenchuk's death loss estimates seem applicable to the predator situation in Wyoming in 2005.

The death loss estimates in Table 1 were used to estimate the total economic benefit from predator management in Wyoming (Table 3). The second column of Table 3 indicates the estimated total number of head by livestock type in Wyoming for 2005 (NASS 2006). The third column of Table 3 illustrates the estimated death loss without predator management. These numbers were derived by multiplying the total head numbers in the second column of Table 3 by the death loss rates in the second column of Table 1. Since there was no death loss estimate for cows in Table 1, cow death loss was assumed to be 14.3 percent of calf death loss. This assumption was based on the ratio between cow and calf death loss for 2005 as reported in the Wyoming Agricultural Statistics (NASS 2006). The total estimated death loss was over 97,000 head, with over 50 percent of this loss being lambs.

The death loss estimates without predator management were then compared to the death lost estimates with predator management. The total number of head by livestock type in the second column of Table 3 were multiplied by the death loss rates in the third column of Table 1 to estimate death loss with predator management. The estimates of death loss with predator management are presented in column four of Table 3. The total estimated death loss with predator management decreases to approximately 30,000 head, with nearly 60 percent of this total being lambs.

The estimates of the net reduction in death loss with predator management are summarized in column five of Table 3. This net reduction represents the difference between column three and column four. The total reduction in death loss due to predator management is estimated to be more than 67,000 head based on the death loss figures presented in Table 1.

NASS (2006) market values per head by livestock type for Wyoming in 2005 are presented in column six of Table 3. These values were multiplied by the net reduction in death loss to estimate the total economic benefit from predator management (column seven of Table 3). The results of this analysis indicated that the total benefit was nearly $14.0 million. Due to their higher market value nearly 50 percent of the total benefit is from reduced calf losses. Market values were used to measure economic benefit under the assumptions that most of the production costs are incurred before the grazing season and that most of the predator losses occur during grazing season.

Because the total death loss in Table 3 slightly exceeded the NASS (2006) death loss estimates for Wyoming in 2005 (30,367 vs. 28,000) an alternative method of estimating total benefits from predator management was calculated for comparative purposes (Table 4). With this method the NASS (2006) death loss estimates for Wyoming in 2005 were used in the "death loss with predator management" column. Estimates of the death loss without predator management were then calculated based on the percent change in death loss without predator management reported in Table 1. For example the NASS estimate of 3,500 head death loss for calves with predator management in Table 3 was increased to 13,125 head without predator management based on the ratio of death loss with predator management to the death loss without predator management in Table 1. The rest of the calculations in Table 4 are the same as in Table 3. The results from this analysis indicated that the total benefit from predator management was more than $9.5 million. The total benefits estimate is slightly lower with this method due to the reduced number of animals lost and the higher proportion of the loss animals that were lambs.

In order to estimate the cost of predator management in Wyoming, three categories of predator management costs were considered. The first category was expenditures by the Wyoming Office of the USDA-APHIS Wildlife Services. Information from Wildlife Services indicated that their total expenditures for predator management in Wyoming were $1.8 million in 2005 (Table 5). Wildlife Services also noted that Cooperators in Wyoming contributed more than $717,000 to joint predator management efforts in 2005. These expenditures are presumably by County Predator Boards and individual livestock producers which are considered separately in the analysis.

A second category of cost information was associated with the County Predator Boards in Wyoming. These boards are funded through a per head predator fee that is collected from livestock producers by brand inspectors. It was assumed that these funds were expended for predator management in the year that they were collected. The Wyoming Livestock Board data indicated that gross predator fee collection for 2005 totaled nearly $612,000 (Table 5). Allowing for the three percent collection fee, nearly $594,000 was assumed to have been spent by County Predator Boards for predator management in Wyoming during 2005.

The final category of cost information was direct spending by livestock producers. Livestock producers in Wyoming engage in a number of, primarily, non-lethal predator control methods. Table 6 summarizes NASS (2005 and 2006) estimates of the percent of Wyoming producers that engage in individual non-lethal control methods in 2004 and 2005. For sheep producers the most common methods were guard dogs (57 percent), night penning (56 percent), llamas (50 percent), and fencing (48 percent). On average, the data indicated that a typical sheep producer in Wyoming engaged in three non-lethal control methods of predator control. For cattle producers the most common methods of predator control were frequent checks (48 percent), culling (42 percent), and livestock carcass removal (33 percent). On average, the data indicated that a typical cattle producer in Wyoming engaged in two non-lethal control methods of predators.

Limited information is available on the cost of these direct predator control activities by producers in Wyoming. Jahnke, et al (1988), found that the direct cost of predator management for large Wyoming sheep producers was $1.65 per head of stock sheep in 1981. In inflation-adjusted dollars this would represent an expenditure of $3.15 per head in 2005. This amount is substantially higher than the per head national estimate derived from NASS (2005) for sheep production in the U.S. Since the sheep industry in Wyoming is primarily range flocks, predator management is likely to be relatively more expensive in Wyoming than the national average, the higher amount ($3.15) was used in the analysis. No studies of the cost of predator management to Wyoming cattle producers are known to exist. For this reason the analysis used the per head national estimate for cattle production of $1.91 derived from NASS (2006). Based on the per head estimates for both sheep and cattle it is estimated that at 2005 inventory levels the direct cost of predator management to Wyoming livestock producers was approximately $3.7 million (Table 5).

Combining the three categories of predator management costs, it is estimated that the total cost of predator management in Wyoming for 2005 was $6.0 million (Table 5). If the estimates of the direct cost of predator control methods to livestock producers in Wyoming are correct, the total cost estimates suggest that the livestock producers in the state, either through direct costs or through predator fees, supported more than 70 percent of total costs of predator management in Wyoming in 2005, with the remaining 30 percent coming from Wildlife Services.

Having developed estimates of both the benefits and costs of predator management in Wyoming, it is now possible to estimate the net benefits and the benefit-cost ratio of the predator management program in the state. Under Method #1 of estimating the benefits of predator management, the estimated benefits were nearly $14 million (Table 3). This compares to an estimated total cost of $6.0 million (Table 5). Subtracting costs from benefits indicates an estimated net benefit of $7.9 million in 2005 and a benefit-cost ratio of $2.30 dollars of benefits for $1.00 of expenditures (Table 7).

Under Method #2 of estimating the benefits of predator management, the estimated benefits were nearly $9.6 million (Table 4). Again, this compares to an estimated cost of $6.0 million (Table 5). Subtracting costs from benefits indicates an estimated net benefit of $3.5 million in 2005 and a benefit-cost ratio of $1.60 of benefits for $1.00 of expenditures (Table 7).

As previously mentioned it is difficult to estimate what the death loss of livestock would be without predator management. Due to this difficulty a breakeven analysis was conducted to determine the minimum amount of a predation management benefits needed for the management effort to be cost effective. Under Method #1 of estimating the benefits of predator management, the net reduction in predator loss would have to be slightly more than 29,000 head in order for the program to be cost effective (Table 8). This is about 40 percent of the 67,108 head reduction estimate for Method #1 (Table 3). Under Method #2 of estimating the benefits of predator management, the net reduction in predator loss would have to be slightly more than 37,000 head for the program to be cost

effective (Table 8). This is about 60 percent of the 58,752 head reduction estimated for Method #2.

Summary and Conclusion

Preliminary estimates of the economic benefit of predator management in Wyoming indicate that the total benefits for livestock production range from $9.5 to $13.9 million in 2005. From a cost perspective, the total cost of the predator management program in Wyoming for 2005 was estimated to be $6.0 million. These costs include expenditures by Wildlife Services, County Predator Boards, and livestock producers to mange predation.

Based on the $13.9 million in total benefits for livestock production, the net benefit of predator management is estimated to be $7.9 million and the benefit-cost ratio is $2.30 of benefits per $1.00 of costs. Based on the $9.5 million in total benefits for livestock production, the net benefit of predator management is estimated to be $3.5 million and the benefit-cost ratio is $1.60 of benefits per $1.00 of costs.

Due to the difficulty in estimating what the death loss would be for livestock without predator management, a breakeven analysis was conducted to determine the minimum amount of predator management benefits needed for the effort to be cost effective. Under Method #1, the net reduction in predator losses would have to be slightly more than 29,000 head in order for the effort to be cost effective. This was about 40 percent of the 67,108 head reduction estimated for Method #1. Under Method #2, the net reduction in predator loss would have to be slightly more than 37,000 head in order for the effort to be cost effective. This is about 60 percent of the 58,752 head reduction estimated for Method #2.

This analysis represents preliminary estimates of the benefits and costs of predator management in Wyoming. These estimates will be refined as the project progresses. In addition to livestock production the economic benefits from predator management to wildlife populations will also be considered. Finally, the project will evaluate trends in predation in Wyoming, the effects of predation on ranch profitability, and the economic impact of predation on the Wyoming economy.

Table 1. Comparison of Death Loss With and Without Predator Management

Livestock Type	Death Loss With Predator Management	Death Loss Without Predator Management	Percent Change in Death Loss
Calves	0.8%	3.0%	275.0%
Sheep	1.6%	5.6%	250.0%
Lambs	6.0%	17.5%	191.7%

Source: Bodenchuk, et al (2000)

Table 2. Comparison of Death Loss with Predator Management

Livestock Type	Death Loss (Bodenchuk, et al)	Death Loss (Wyoming NASS)
Calves	0.8%	0.5%
Sheep	1.6%	0.9%
Lambs	6.0%	7.0%
Total	**2.1%**	**2.0%**

Source: Bodenchuk et al (2000) and NASS (2006)

Table 3. Estimated Total Benefits from Predator Management – Method #1

	Total Head 2005	Death Loss Without Predator Management	Death Loss With Predator Management	Net Reduction	Market Value (2)	Total Benefit Predator Management
Calves	740,000	22,200	5,920	16,280	$420.00	$6,837,600
Cows (1)	760,000	3,175	847	2,328	$1,113.00	$2,591,109
Sheep	350,000	19,600	5,600	14,000	$143.00	$2,002,000
Lambs	300,000	52,500	18,000	34,500	$72.60	$2,504,700
Total	**2,150,000**	**97,475**	**30,367**	**67,108**		**13,935,409**

(1) Assumes that cow death loss is 14.3% of calf death loss (NASS 2006)
(2) Market value is used assuming most production costs are incurred before grazing season

Table 4. Estimated Total Benefits from Predator Management – Method #2

	Total Head 2005	Death Loss Without Predator Management	Death Loss With Predator Management	Net Reduction	Market Value (1)	Total Benefit Predator Management
Calves	740,000	13,125	3,500	9,625	$420.00	$4,042,500
Cows	760,000	1,877	500	1,377	$1,113.00	$1,532,462
Sheep	350,000	10,500	3,000	7,500	$143.00	$1,072,500
Lambs	300,000	61,250	21,000	40,250	$72.60	$2,922,150
Total	**2,150,000**	**86,752**	**28,000**	**58,752**		**9,569,612**

(1) Market value is used assuming most production costs are already incurred by grazing season

Table 5. Cost Analysis for Predator Management in Wyoming

	Amount	Percent
Federal Wildlife Services	$1,778,158	29.4%
Predator Fee Collections		
Gross Collections	$611,968	
Collection Fee @ 3%	$18,359	
Net Revenue	$593,609	9.8%
Producers (1)	$3,675,938	60.8%
Total Costs	**$6,047,705**	**100.0%**

(1) Based on $3.15 per head of breeding sheep and $1.91 per head of cattle and calves

Table 6. Non-Lethal Methods Use to Prevent Losses to Predators, Wyoming

	Sheep Producers 2004		Cattle Producers 2005
Fencing	48.3%	Guard Animals	20.9%
Guard Dogs	56.9%	Exclusion Fencing	20.5%
Llamas	50.3%	Herding	10.0%
Donkeys	3.4%	Night Penning	21.6%
Lamb Shed	18.0%	Frequent Checks	48.0%
Herding	6.5%	Fright Tactics	0.5%
Night Penning	55.7%	Carcass Removal	32.7%
Fright Tactics	1.6%	Culling	42.0%
Removing Carrion	2.7%	Other	12.2%
Culling	6.6%		
Change Bedding	3.3%		
Frequent Checks	11.7%		
Other	7.2%		

Source: National Agricultural Statistics Service

Table 7. Benefit-Cost Analysis for Predator Management in Wyoming

	Method #1	Method #2
Estimated Benefits:		
Calves	$6,837,600	$4,042,500
Cows	$2,591,109	$1,532,462
Sheep	$2,002,000	$1,072,500
Lambs	$2,504,700	$2,922,150
Total	**$13,935,409**	**$9,569,612**
Estimated Costs:		
Federal Wildlife Services	$1,778,158	$1,778,158
Predator Boards	$593,609	$593,609
Livestock Producers	$3,675,938	$3,675,938
Total Costs	**$6,047,705**	**$6,047,705**
Net Benefit	$7,887,703	$3,521,907
Benefit-Cost Ratio	2.3	1.6

Table 8. Breakeven Analysis for Predator Management in Wyoming

Breakeven for Method #1

	Net Benefits W/ PM	Breakeven Benefits	Market Value (NASS)	Breakeven Net Reduction
Calves	$6,837,600	$2,967,390	$420.00	7,065
Cows	$2,591,109	$1,124,492	$1,113.00	1,010
Sheep	$2,002,000	$868,830	$143.00	6,076
Lambs	$2,504,700	$1,086,993	$72.60	14,972
Total	**$13,935,409**	**$6,047,705**		**29,124**

Breakeven for Method #2

	Net Benefits W/ PM	Breakeven Benefits	Market Value (NASS)	Breakeven Net Reduction
Calves	$4,042,500	$2,554,738	$420.00	6,083
Cows	$1,532,462	$968,470	$1,113.00	870
Sheep	$1,072,500	$677,788	$143.00	4,740
Lambs	$2,922,150	$1,846,710	$72.60	25,437
Total	**$9,569,612**	**$6,047,705**		**37,129**

Section III: The Effects of Predator Death Loss on Ranch Profitability

Introduction

Predator damage represents a significant cost to Wyoming agricultural producers. The Wyoming Field Office of the National Agricultural Statistics Service (NASS) estimates that the agricultural industry in Wyoming lost 4,000 cattle and calves and 24,000 sheep and lambs to all predators during 2005 (NASS, 2006). NASS estimates that the market value of this lost livestock was nearly $4.0 million. These losses negatively affect ranch profitability. Predators could potentially reduce ranch profitability through three mechanisms: 1) increased death loss, 2) reduced weaning weights due to stress, and 3) increased labor and management costs. This analysis focuses on the effects of increased death loss from predation on ranch profitability in Wyoming.

Previous research has shown that predators such as grizzly bears and gray wolves can increase livestock death loss. In Northwest Alberta, Bjorge (1983) found a 2.0 percent calf death loss rate on summer grazing pastures where predation was uncommon and a 5.7 percent calf death loss rate on pastures with grizzly and wolf predation. In Northwest Wyoming, Anderson et. al (2002) found a 2.5 percent average annual calf death loss rate prior to confirmed grizzly predation and an average annual calf death loss rate of 6.2 percent after grizzly predation was confirmed. Anderson also notes that of 8 adult bears monitored, three were responsible for 90 percent of all identifiable losses. Sommers et. al (2008) in a study of the Upper Green River Cattle Allotment in western Wyoming found that the calf death loss rate on summer pasture in the study area increased from a historic average of 2.0 percent without predators to an average of 4.0 percent with grizzlies and an average of 5.7 percent with both grizzlies and wolves. They also report calf death loss rates as high as 8.1 percent. This is consistent with Anderson et al who reported calf death loss rates as high as 12.4 percent. Both Anderson and Sommers found that most common victims of predation were calves (90 percent and 87 percent respectively).

The objective of this analysis is to use the research on calf death losses from predation to estimate the effects of predation on ranch profitability. While references in this analysis relate to grizzly bear and gray wolf predation, the results of the analysis would also apply to calf death losses from other predators.

Methods

We use a computerized ranch model to simulate the economic effects of increased death loss. The Western Wyoming Grazing Model (WWGM) uses a multiyear linear programming framework originally developed for the W-192 (now W-1192) USDA Regional Research Project (Torell et. al 2002). The model solves for the profit maximizing herd size and forage use given a defined cattle price scenario. In the process, the profit-maximizing livestock sales and ranch income are also determined. The results from the first year solution are used as starting conditions for the second year. This process continues for 40 years with optimal production levels chosen to maximize the net present value of ranch profits chosen for each year. Because the ranch faces fluctuations

in cattle prices, the model uses 100 sets of random prices that ranchers likely would face over the 40-year planning horizon. The results reported below are the average level of production and profit realized across the 100 alternative cattle price scenarios (Tanaka et. al 2007).

With assistance from the original authors, the ranch modeling framework discussed above was modified in the WWGM to reflect the production characteristics of ranching operations in Western Wyoming. This modification was based on previous analysis in Fremont and Park Counties (Taylor et. al 2004, 2005). Once the model is operational, changes in production and profitability levels relative to the base line (no predation death loss) can then be observed by changing parameters in the model and re-running the 40 year horizon. The model ranch was setup to be sufficiently large to serve as the primary income source for a ranching household under the base scenario.

Results

In this analysis the WWGM was modified to reflect increases in calf death loss. Previous research has indicated that predators can increase livestock death loss rates (Anderson et. al, 2002, Bjorge (1983), and Sommers et. al (2008) with combined summer pasture calf death loss rates as high as 12 percent. This research has also shown that the majority of this death loss from predators was calves. In this analysis, the death loss ratios for calves are changed in four different scenarios to show the effects of increased death loss on ranch productivity and profits. The source of the death loss is not specified in the model and could come from any source. The baseline scenario uses a four percent death loss ratio for calves, assuming two percent for summer grazing on public land and two percent for the rest of the year. The other three scenarios simulate alternative predation rates by increasing the death loss ratio in two percent increments to 10 percent.

Table 9 outlines the results for the four scenarios with gross revenue, net livestock returns, ranch profits, percent of years negative, cows, calves and tons of alfalfa hay sold. In the base model (4% death loss), the ranch had gross revenue of $244,163; net livestock returns totaled $65,172 with ranch profits of $27,822. There are 610 mother cows producing 569 calves (accounting for conception rates and death loss). The ranch also sells 169 tons of hay.

As death loss rates increase, ranch profits decrease due to the decrease in the number of calves sold. At a 6 percent death loss ratio for calves, herd size declines marginally as the ranch tries to maintain its operation; however, less calves are weaned and more heifer calves need to be retained as replacements to maintain herd numbers, undercutting profitability. Gross returns decline only slightly (3 percent) as an increase in hay sales of 10 tons helps offset increased death loss of calves. However, ranch profits decrease almost 20 percent with just a two percent increase in calf death loss (from 4 percent to 6 percent) because fixed costs are unchanged.

When calf death loss is adjusted to 8 percent, gross returns decrease by 6 percent from the base case scenario, while the number of mother cows is reduced by 3.6 percent. Hay

sales increase by 21 percent to 184 tons. Again, in order to maximize profit, the model is adjusting by slightly reducing herd size and selling additional hay. These numbers do not seem extreme until ranch profits are taken into account. Ranch profits decrease by over 40 percent from the base case. This is because the ranch has high fixed costs in its asset base, i.e. land and cattle. The producer must cover these fixed costs in order to stay in business in the long-term. Calves, being the end product from a long production process represent the profit center of the business. Removing calves, through death loss, effectively removes profit from the business.

Table 9. Simulation model results for increased death loss of calves.

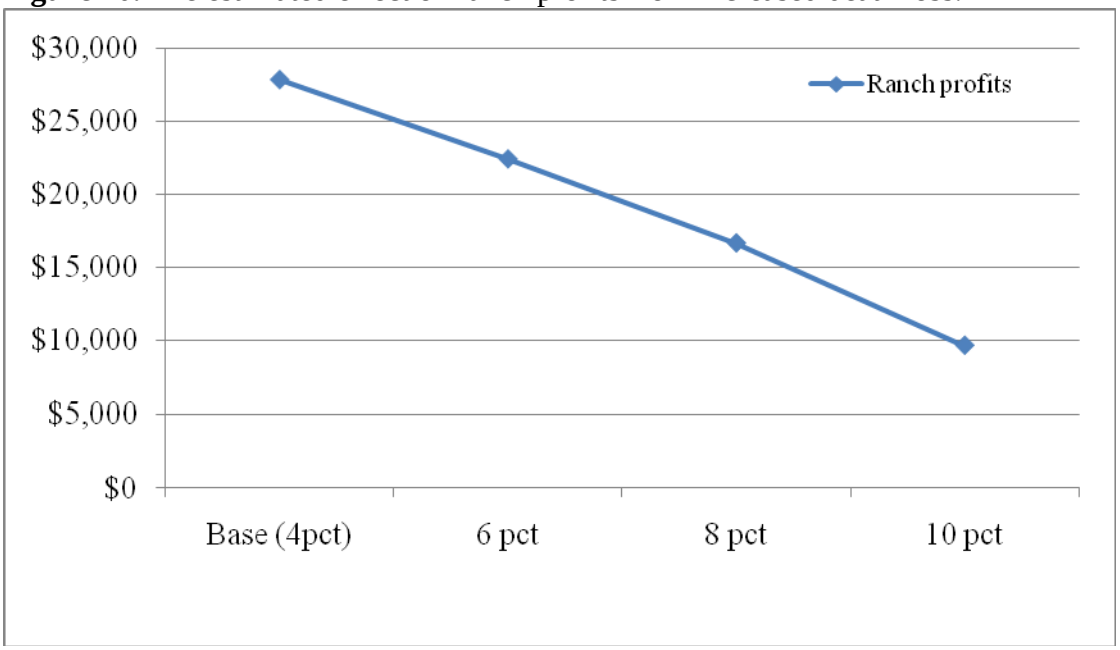
	Gross revenue	**Net livestock returns**	**Ranch profits**	**Percent negative years**	**Mother cows**	**Calves**	**Alfalfa sold (tons)**
Base (4pct)	$244,163	$65,172	$27,822	32%	610	569	169
6 pct	$237,077	$59,741	$22,391	35%	600	560	184
8 pct	$229,272	$53,993	$16,643	39%	588	548	204
10 pct	$219,269	$46,984	$9,634	44%	566	529	239
Percent change from base model							
6 pct	-2.90	-8.33	-19.52	-1.58	-1.64	-1.58	8.88
8 pct	-6.10	-17.15	-40.18	-3.69	-3.61	-3.69	20.70
10 pct	-10.20	-27.91	-65.37	-7.03	-7.21	-7.03	41.42

Ranch profits decline by over 65 percent in the 10 percent calf death loss scenario. At this level of death loss, the model has optimized by increasing hay sales by 41 percent over the base case scenario in order to try and compensate for the high level of death loss. Herd size has decreased by more than seven percent from the base case, but more heifer calves are going back into the herd, instead of being sold, increasing fixed costs (raising cows) instead of being sold and generating profits.

The overall trend in ranch profits across the scenarios is shown in Figure 10. Ranch profits decrease at an increasing rate as death loss levels increase. Long-term profitability for the operation comes into question, even at a sustained six percent death loss and it is likely that by 10 percent, the operation would not remain viable without additional sources of income.

Increased death loss also increases the variability of income as seen by the increase in the percent of negative years in the scenario. In the base case, there are 1,264 years of negative income out of the 4,000 years (40 years, times 100 runs per year). Thus approximately 3 in 10 years (32 percent) are negative for the ranching operation. As death loss rates increase, this number climbs at an increasing rate, so that given a 10 percent death loss for calves; the number of negative years is 1,650 or an average of 4 negative years in 10 for the operation. Increased income variability increases stress on management and increases the chances that the business will fail.

Figure 10. The estimated effect on ranch profits from increased death loss.



Section IV: Literature Review: Economics of Predator Control

Economic theories and models can inform a wide range of predator control questions, from deciding which control methods are cost effective to examining whether predator control improves social welfare. Despite this applicability and a long history of predator management in the US, there are relatively few rigorous economic analyses of predator control. The objective of this literature review is to summarize existing research to inform both current policy and to highlight future research directions. This objective is accomplished with three components: 1) a review of economic methods applicable to predator control, 2) a summary of existing economic analyses of predator control, and 3) an extensive annotated bibliography of existing economic analyses of predator control.

The first component provides a brief review of a wide range of economic models that are particularly well suited to answering predator control questions. The models considered include cost-effectiveness analysis, cost-benefit analysis, return on investment analysis, and general equilibrium/regional input-output modeling. We discuss the advantages and disadvantages of each model in the context of predator control, and consider the types of questions each model is best able to answer. [This component will be completed in grant year two]

The second component provides a thorough summary of existing economic analyses of predator control. The summary highlights how existing research can inform predator control policies in Wyoming, describes strengths and weaknesses of existing applications and identifies fertile areas for future research. [This component will be completed in grant year two]

The final component provides a quick reference to all of the literature examined for this review. For each item, we provide a brief annotation describing the context, methods and results. This will give policy-makers and future researchers the ability to quickly identify relevant research. [In progress]

Categorization of Literature Reviewed

Article	Case Study	State or National Study	Theoretic Model	Applied Model	Statistical Analysis	Exogenous Trend Variable	Data Set Included	Cost Estimates	Benefit Estimates	Net Benefits (BCA)	Wildlife	Livestock
2007												
Frey & Conover	X				X						X	
Schiess-Meier, Ramsauer, Gabanapelo, & König	X			X	X	X	X	X	X	X	X	X
Wyoming Game and Fish Department		X		X	X				X		X	
2006												
Blejwas, Williams, Shin, McCullough, & Jaeger	X							X				X
Berger		X		X	X	X		X	X	X		X
Duffield, Neher, & Patterson	X				X		X		X	X	X	X
Shivik								X				X
Shwiff, Sterner, Kirkpatrick, & Engeman		X					X	X	X	X		X
Skonhoft		X	X	X			X	X	X	X	X	
2005												
Bright & Hervert	X			X		X	X	X			X	
Shwiff, Sterner, Turman, & Foster	X			X	X	X	X	X	X		X	
2004												
Allen & Fleming		X		X			X	X	X			X
Andelt							X	X				X
Asheim & Mysterud		X		X	X		X	X	X	X		X
Brek & Meier		X					X		X			X
Article	Case Study	State or National Study	Theoretic Model	Applied Model	Statistical Analysis	Exogenous Trend Variable	Data Set Included	Cost Estimates	Benefit Estimates	Net Benefits (BCA)	Wildlife	Livestock
2004 Continued												

Engeman, Shwiff, Smith, & Constantin								X			X	X
Fagerstone, Johnston, & Savarie								X				X
Jaeger								X				X
Jones		X		X			X		X			X
Shivik								X				X
Shwiff & Bodenchuk							X		X			X
Shwiff & Merrell	X						X	X	X	X		X
2003												
Engeman, Shwiff, Cano, & Constantin	X			X			X	X	X	X	X	
2002												
Anderson, Ternent, & Moody	X			X	X		X		X			X
Engeman, Shwiff, Constantin, Stahl, & Smith	X			X				X	X	X	X	
2000												
Bodenchuk, Mason, & Pitt		X		X			X	X	X	X	X	X
Yoder			X					X	X	X		X
1999												
Phillips & Martley		X								X		X
Wagner & Conover	X			X	X			X	X	X		X

Article	Case Study	State or National Study	Theoretic Model	Applied Model	Statistical Analysis	Exogenous Trend Variable	Data Set Included	Cost Estimates	Benefit Estimates	Net Benefits (BCA)	Wildlife	Livestock
1998												
Conner, Jaeger, Weller, & McCullough	X			X	X				X			X
1997												

Collinge & Maycock	X			X			X	X	X	X		X
1995												
Henke & Knowlton								X				X
1993												
Connolly		X						X				X
1986												
Smith, Neff, & Woolsey	X			X			X	X	X	X	X	
Terrill		X		X			X		X			X

.

Annotated Bibliography

2007

Journal Articles

Frey, S. N., and M. R. Conover. "Influence of Population Reduction on Predator Home Range Size and Spatial Overlap." *Journal of Wildlife Management* 71, no. 2(2007): 303-309.

This paper examines the effects of predator removal on the behavior of other predators in the Bear River Migratory Bird Range, Utah. Of the three species examined (red fox, striped skunks, and raccoons), home range size remained the same, although individuals spread out causing less overlap with same species predators. Foxes and raccoons (competing predators) however did not disperse probably because of the abundance of native prey.

Schiess: Meier, M., et al. "Livestock Predation-Insights From Problem Animal Control Registers in Botswana." *Journal of Wildlife Management* 71, no. 4(2007): 1267-1274.

This article investigates livestock losses due to predation by leopards, lions, wild dogs, brown hyenas, and cheetahs over a 3 year period (1999-2002) in the Kweneng district of Botswana. They examine seasonal, regional, and behavioral factors that cause differences in attack rates of predators (lions and leopards). Using statistical methods to analyze livestock losses for spatial and temporal patterns, they determine if attack rates of lions and leopards depend on the abundance of native prey. Results indicate that lions depredate more livestock in dryer times, probably due to a lack of alternative prey.

Reports

Wyoming Game and Fish Department. "An assesment of changes in elk calf recruitment relative to wolf reestablishment in northwest Wyoming." Wildlilfe Division, Wyoming Game and Fish Department, March 23, 2007.

This report examines the effect of wolves on elk calf recruitment in northwest Wyoming. Calf:cow ratios are used to determine future recruitment. A standard of 25-30:100 is used to represent a stable population. Statistical analysis indicates that between 1980 and 2005, six of the eight elk herds that overlapped with wolf packs experienced declining calf:cow ratios. Of the eight, four declined at a greater rate after wolf occupancy. In half of Wyoming elk herds overlapping wolf packs, predation significantly affects elk recruitment. This study, however, did not consider year round precipitation, elk body condition, reproductive rates, or wolf:elk ratios.

2006

Journal Articles

Berger, K. M. "Carnivore-Livestock Conflicts: Effects of Subsidized Predator Control and Economic Correlates on the Sheep Industry." *Conservation Biology* 20, no. 3(2006): 751-761.

Predator control is one of the oldest, most widespread forms of wildlife management. An econometric model using data from 1920-1998 examines several variables that may affect sheep herd sizes over time and space. The variables used were lamb prices, wool prices, hay prices, cattle prices, average wage rates, percent of ranchers over the age of 65, dollars spent on livestock protection (federal and cooperative), and a time variable for the years in which compound 1080 was used for predator control. Multiple regressions of 16 models are evaluated in this article. Akaike's information criterion indicated that the most parsimonious model includes lamb prices, hay prices, wage rates, age, and dollars spent on livestock protection as regressors. This model statistically accounts for 73% of the change in sheep numbers from year to year. This model suggests that control efforts have had little effect on trends in the sheep industry.

Blejwas, K. M., et al. "Salivary DNA Evidence Convicts Breeding Male Coyotes of Killing Sheep." *The Journal of Wildlife Management* 70, no. 4(2006): 1087 - 1093.

It is often difficult to prove which predator depredated livestock. This article discusses DNA evidence as a source of information about individual cases of livestock depredation. DNA evidence provides species and sex information that can be used to corroborate field identification in livestock depredation cases. Results indicate that breeding males coyotes (alphas) were responsible for many depredation cases.

Shivik, J. A. "Tools for the edge: What's new for conserving carnivores." *BioScience* 56, no. 3(2006): 253-259.

There are many ways to deter predators, namely by providing disruptive or averse stimuli that incite behavior modification. This publication provides examples of predator management and their associated economic and biological efficiency. Disruptive stimuli that were examined in this article include fladry (the use of flags to deter predators from entering an enclosed area), *The Electronic Guard* (a sensor that activates strobe lights and sirens at night), plastic protection collars, the *ScareCall* (programmable light and sound device), and radio activated guards (devices that activate when collared predators approach). The article notes that disruptive stimuli are beneficial because they are relatively less expensive; however, such devices are not always effective for all predators. Behavior modification involves instilling conditioned responses against livestock depredation in individual predators usually by harassment, taste aversion, or

electric shock. These techniques work well with some predators and not at all with others. Eliciting conditioned responses from offending predators are biologically effective in reducing predation. Behavior modification is usually more expensive and requires significant time investments.

Skonhoft, A. "The Costs and Benefits of Animal Predation: An Analysis of Scandinavian Wolf Re-colonization." *Ecological Economics* 58, no. 4(2006): 830-841.

This article provides an economic framework for efficient harvesting of large game (moose) when there is some level of predation (wolves). Predators affect large wildlife populations in a dynamic ecosystem. For the purpose of this article, ownership of wildlife is assigned to property owners who control the means in which the game is harvested. Four potential management practices for the harvesting of large game are examined. These are threshold harvesting, proportional harvesting, fixed quota harvesting, and maximizing present-value profit. Predation effects on profits depend on the management practices employed. Under the profit maximizing scheme, profits fall by more than 10% and losses may be higher for proportional harvesting schemes.

Reports

Duffield, J., C. Neher, and D. Patterson. "Wolves and People in Yellowstone: Impacts on the Regional Economy." University of Montana, Department of Mathematical Sciences, September 2006.

This report provides an economic impact assessment of wolves on the Greater Yellowstone Area. A contingent valuation survey conducted in Yellowstone Park indicates that $35,520,929 in annual expenditures in Montana, Wyoming, and Idaho is attributable to wolves. It further indicates that increased patronage in 2005 added an additional $18 to $30.6 million dollars. This report also states that Wolf predation has a moderate impact on elk and livestock populations. Final results indicate that wolves are responsible for a net benefit between $52.9 and $66.2 million.

Shwiff, S. A., et al. "Benefits and Costs Associated with Wildlife Services Activities in California." 22nd Vertebrate Pest Conference Proceedings.

This report discusses the benefits of the Wildlife Services (WS) program in California by providing estimates for (1) prevented damage, (2) the cost of a program that could replace WS and provide the same services, and (3) cooperative costs. Results indicate that the WS program provides more benefit to local economies than a replacement programs could because of efficiency from economies of scale. The Wildlife Services program is established and utilizes vast resources to mitigate wildlife damage. The report estimates total benefits from Wildlife Services are between $5,758,612 and $10,625,890 per year.

2005

Journal Articles

Bright, J. L., and J. J. Hervert. "Adult and fawn mortality of Sonoran pronghorn." *Wildlife Society Bulletin* 33, no. 1(2005): 43-50.

This article discusses the adult mortality of a limited population of Sonoran Pronghorn in Arizona. Of 32 mortalities, 12 were a result of predation.

Shwiff, S. A., et al. "Ex post economic analysis of reproduction-monitoring and predator-removal variables associated with protection of the endangered California least tern." Ecological Economics 53, no. 2(2005): 277-287.

This paper documents predator removal and reproduction-monitoring costs of protecting the California Least Tern to determine whether these programs affect the observed number of Tern adults, nests, and fledglings. Using data from 1995-2001, statistical analysis is performed using the number of adult Terns, nests, eggs, fledglings, active nests, incubating eggs, predators removed, hours spent removing predators, monitoring hours, total hours, the amount of precipitation, average temperature, average wind speed, the dew point, and another variable to account for adverse events. The report also examines the number of predators removed and the associated costs of predator removal and reproduction-monitoring. Results of this study indicated that the economic variables (cost of predator removal and reproduction-monitoring) were at least as significant as biological variables and more potent than meteorological variables.

2004

Journal Articles

Allen, L. R., and P. J. S. Fleming. "Review of Canid Management in Australia for the Protection of Livestock and Wildlife - Potential Application to Coyote Management." *Sheep and Goat Research Journal* 19(2004): 97-104.

This article discusses the capture efficiency of canids (red wolves and wild dogs) attacking prey, a summary of management methods, and the direct costs to the Australian government. In 2003, the costs of wild dogs on the rural economy (predation losses and control) were A$33,108,000 in Queensland alone. This article also discusses the ramifications of predation on reptiles, foraging birds, and small mammals.

Andelt, W. F. "Use of Livestock Guarding Animals to Reduce Predation on Livestock." *Sheep and Goat Research Journal* 19(2004): 72-75.

Livestock guarding animals are used to reduce the amount of livestock predation. Costs associated with guarding animals are a key control cost in predator management. Dogs, llamas, and donkeys are the most common guarding animals.

This article outlines benefits and drawbacks of each animal as well as discussing costs for each. Dogs are effective in deterring coyotes, bears, and mountain lions, but may not be effective against wolves. Drawbacks of dogs include not staying with sheep, being overly aggressive toward people, requiring different food than sheep, and harassing sheep. Llamas eat the same food as sheep and are aggressive toward canids; however, intact llamas may attempt to breed with ewes and they are relatively expensive ($600 and $800). Donkeys typically dislike canids as well, will protect sheep, eat the same food, and cost between $144 and $236. Disadvantages are that multiple donkeys will stay together, some donkeys are not aggressive toward canids, they may trample lambs, and intact jacks are too aggressive to be kept with sheep.

Asheim, L. J., and I. Mysterud. "Economic Impact of Protected Large Carnivores on Sheep Farming in Norway." *Sheep and Goat Research Journal* 19(2004): 89-96.

A study of Norwegian sheep producers using the number of predators from 1994 and sheep losses from 1988-1993 reports that the main cost of predators is the value of the lost animal. Among other costs cited were (1) loss of subsequent breeding, (2) replacing fertile ewes with less fertile lambs (3) costs associated with a lamb losing its mother (4) costs associated with mothers losing their lamb, and (5) extra labor to protect from predators. Results of this study indicate that the cost of predation on Norwegian sheep farming is between US$3,000,000 and US$12,900,000. These costs are broken down between lynx, wolverines, golden eagles, and bears/wolves; bears/wolves account for most of the cost.

Brek, S., and T. Meier. "Managing Wolf Depredation in the United States: Past, Present, and Future." *Sheep and Goat Research Journal* 19(2004): 41-46.

This article focuses on pre- (1979-1991) and post-reintroduction (2000-2002) wolf predation rates in Minnesota and Montana. They point out that (1) the overall impact on the livestock industry was small relative to other factors like adverse weather and disease, (2) the rate of depredation remained relatively constant from 1979-2002 despite changes in wolf populations, and (3) sheep are more vulnerable to attack by wolves than cattle (sheep depredation rates were 2 to 30 times higher).

Engeman, R. M., et al. "Monetary valuation methods for economic analysis of the benefit-costs of protecting rare wildlife species." *Integrated Pest Management Reviews* 7(2004): 139-144.

This publication lays out several monetary valuation methods including contingent valuation, legislatively designed values, and breeding costs. Benefits and drawbacks to each method are also discussed. Depending on the situation, different methods may be more or less appropriate.

Fagerstone, K. A., J. J. Johnston, and P. J. Savarie. "Predacides for Canid Predation Management." *Sheep and Goat Research Journal* 19(2004): 76-79.

Predacides are chemical controls used primarily on predatory canids. This article outlines the use of three predacides (gas cartridges, sodium cyanide\M-44's, and compound 1080) as well as their benefits, relative costs, effectiveness and risks. Gas cartridges are most effective to control coyotes, foxes, and skunks in their dens while they are rearing young. Cartridges pose few non-target risks, and the EPA has no concern over their ingredients. M-44's are devices that contain sodium cyanide capsules that are injected into the predator with a spring driven plunger. The use of Sodium Cyanide was outlawed by the EPA in 1972 because of non-target hazards; however, few non-target animals are killed by M-44's and sodium cyanide poses no risk to the environment. The limited use of M-44's is now regulated by APHIS. Compound 1080 is currently used in livestock protecting collars. Environmental hazards of 1080 are minimal.

Jaeger, M. M. "Selective Targeting of Alpha Coyotes to Stop Sheep Depredation." *Sheep and Goat Research Journal* 19(2004): 80-84.

Studies have shown that some coyotes are more likely to attack livestock than others. 'Alpha' pairs in particular depredate the majority of livestock. Management techniques which are selective of alpha pairs are likely to be the most successful. This article suggests that the use of livestock protection collars, denning, guarding animals, and calling-and-shooting, to selectively target alphas.

Jones, K. "Economic Impact of Sheep Predation in the United States." *Sheep and Goat Research Journal* 19(2004): 6-12.

Many studies that investigate the costs of predation examine only the direct losses agricultural producers suffer. It is important to note that additional costs result from predation losses to agricultural inputs. These losses include value added, employment generated by sheep production, and industry output. This article shows that even though sheep production accounts for a very small amount of the national economy, sheep depredation has a large impact. Nation-wide estimates of direct losses for 1999 were $16,438,850. Total losses were estimated to be $28,969,262.

Shivik, J. A. "Non-lethal Alternatives for Predation Management." *Sheep and Goat Research Journal* 19(2004): 64-71.

This article examines non-lethal alternatives for predation management. Insurance, animal armor, fencing, herding/vigilance, selective pasturing, chemical repellents, and other disruptive stimuli are suggested. Non-lethal methods tend to deter certain predator behaviors and are not effective when the predator populations are large.

Shwiff, S. A., and M. J. Bodenchuk. "Direct, Spillover, and Intangible Benefits of Predation Management." *Sheep and Goat Research Journal* 19(2004): 50-52.

This article discusses three types of benefits of predation management that should be considered to get a comprehensive list of benefits. These benefits are (1) direct (the number of individual animals saved from predation), (2) spillover (e.g. non target species saved as a result of predation management), and (3) intangible (e.g. increased cooperation from landowners and benefits that are not easily quantified).

Shwiff, S. A., and R. J. Merrell. "Coyote Predation Management: An Economic Analysis of Increased Antelope Recruitment and Cattle Production in South Central Wyoming." *Sheep and Goat Research Journal* 19(2004): 29-33.

A cost-benefit analysis of coyote removal (aerial hunting and M-44's) in two areas of Carbon County, Wyoming indicates that coyote predation management has the potential to increase Wyoming revenues by $200,000 to $400,000 annually. Using a range of values for cattle and antelope several cost-benefit ratios were determined. All of which considered coyote removal cost effective.

2003

Journal Articles

Engeman, R. M., et al. "An economic assessment of the potential for predator managemnet to benefit Puerto Rican parrots." *Ecological Economics* 46(2003): 283-292.

This paper is a case study of the endangered Puerto Rican parrot and its natural predators (mongoose, rat, and felines). First, monetary values for the parrot are established by examining captive breeding costs. Next, the costs of predator management are determined and a benefit-cost analysis is performed. The results indicated that so long as 1.4 parrots were saved per year, the management is cost effective.

2002

Journal Articles

Anderson, C. R., Jr., M. A. Ternent, and D. S. Moody. "Grizzly Bear-Cattle Interactions on Two Grazing Allotments in Northwest Wyoming." *Ursus* 13, no. (2002): 247-256.

A study of Northwest Wyoming estimated the number of Grizzly predation incidents within a limited area. This study shows which cattle are more at risk, the number of grizzly associated depredation cases, as well as which bears are more likely to depredate livestock. Findings suggest that grizzly bears from most sex-age cohorts will opportunistically prey on cattle.

Engeman, R. M., et al. "An economic analysis of predator removal approaches for protecting marine turtle nests at Hobe Sound National Wildlife Refuge." *Ecological Economics* 42, no. 3(2002): 469-478.

This article examines the economic benefit and efficacy of predator control (armadillos and raccoons) on the Hobe Sound National Wildlife Refuge in Florida. The refuge offers protected habitat for marine turtles. Because captive breeding costs are unavailable for Florida marine turtles, statutory penalties for illegal kills are used as the cost of losing a turtle. Between 1998 and 2000, four approaches to predator control were used: (1) no control; (2) refuge control; (3) refuge control and contracts with control specialists; (4) refuge control, contracts with control specialists, and spatial and temporal predator monitoring. Refuge control is the opportunistic removal of predators by refuge personnel. Estimates for losses are determined for each level of control and compared with their associated costs. The results indicate that it is cost-beneficial to use contracted specialists and to pay for monitoring.

2000

Journal Articles

Yoder, J. K. "Contracting over common property: Cost-share contracts for predator control." *Journal of Agricultural and Resource Economics* 25, no. 2(2000): 485-500.

Since as early as 1630, American livestock owners have paid a fee/head of livestock to fund predator bounties. This article provides a model to examine the benefit of community offered bounties over time and space compared to bounties offered by each producer independently. The model implies tradeoffs between efficiency in cost-sharing and losses from enrollment. The model may have applications in evaluating any number of common property goods.

Reports

Bodenchuck, M. J., J. Russell Mason, and W. C. Pitt. "Economics of predation management in relation to agriculture, wildlife, and human health and safety." USDA National Wildlife Research Center Symposia.

This report examines the cost effectiveness of predator management by considering the costs and benefits to agricultural producers, wildlife resources, and human health and safety. The report uses Federal and cooperative dollar figures for livestock protection to estimate direct costs of predator control in 1998 ($20,504,966). This report also estimates that total economic savings compared to total costs yield a 12.2:1 benefit-cost ratio. Also, intrinsic and extrinsic values for wildlife are calculated using hunting license fees and expenditures to protect endangered species. According to this report, benefit-cost ratios to protect wildlife ranged between 2:1 and 22.6:1. This publication reports that properly

applied predation management shows large benefits in comparison with the costs incurred.

1999

Journal Articles

Wagner, K. K., and M. R. Conover. "Effect of Preventive Coyote Hunting on Sheep Losses to Coyote Predation." *Journal of Wildlife Management* 63, no. 2(1999): 606-612.

This article performs a cost benefit analysis of coyote aerial gunning using treated and untreated pastures for comparison. Aerial hunting to protect livestock occurs in the spring prior to sheep being placed in a pasture. The results indicate a 2.1:1 cost-benefit ratio for aerial gunning on the examined pastures in Utah and Idaho. Estimated losses from coyotes fell from 2.8% to 0.9% in treated pastures. This article indicates that aerial hunting had two benefits: a reduction in lamb losses to coyote predation and a reduction in the hours of summer pasture management.

Reports

Phillips, R. H., and H. Martley. "History of Federal Predator Control in Wyoming: 1915-1999." Wyoming Wildlife Services.

The Wyoming Territorial legislature authorized a 50 cent bounty for wolves in 1875. Federally funded predator control began in Wyoming in 1915. Back then, the Wyoming-South Dakota District of the Biological Survey produced an estimated 1,000% return to government dollars spent. This report contains excerpts and commentary from the annual reports of the early Biological Survey. These excerpts represent some of the first rudimentary benefit-cost analysis of predator control conducted in Wyoming. This report documents methods and costs of statewide predator control from 1918 to 1999.

1998

Journal Articles

Conner, M. M., et al. "Effect of Coyote Removal on Sheep Depredation in Northern California." *The Journal of Wildlife Management* 62, no. 2(1998): 690-699.

This paper documents a study of sheep depredation by coyotes over the period 1981-1994 (minus 1986) in Northern California. Statistical analysis indicates that annual lamb and ewe kills and kill rates were not correlated with the number of coyotes removed. It suggests that this is because most of the coyotes removed were not killing sheep. Offending coyotes may be difficult to remove by conventional means (trapping and snaring). The analysis also indicates that the number of coyotes removed is likely determined by the number of lambs killed, not vice versa. In other words, predation suppression efforts were increased when more lambs were killed. There was also no correlation between removal of

coyotes and reduced predation in subsequent years. This study did not consider coyote densities as data was not available. The paper suggests the need for selective targeting of offending coyotes.

1997

Reports

Collinge, M. D., and C. L. Maycock. "Cost-Effectiveness of Predator Damage Management Efforts to Protect Sheep in Idaho." 13th Great Plains Wildlife Damage Control Workshop

This publication reports on a benefit-cost analysis conducted on predator management in southern Idaho in 1996. Direct costs of predation were estimated using data collected by the Idaho Agricultural Statistics Service which indicated that 3,348 sheep and 11,718 lambs were confirmed lost due to predation at a cost of $1,393,605. These data were then extrapolated to include all predation cases (not just confirmed cases reported by the statistics service). These costs were $4,146,405. Indirect costs (salaries and benefits for staff, supplies, equipment, and vehicle and aircraft expenses) were estimated at $664,261. Total costs of predation divided by the cost of administering predation management programs yield a benefit-cost ratio of 3.14:1.

1995

Reports

Henke, S. E., and F. F. Knowlton. "Techniques for Estimating Coyote Abundance." Wildlife Damage Management Symposium.

Assessing relative predator density is an important component of economic predator management. This report discusses several techniques for estimating coyote abundance. Techniques include: (1) aerial counts (visual or infrared), (2) catch-mark-release (3) spotlight counts, (4) catch-per-unit effort, (5) scent station visitation rates, (6) elicited howling responses, (7) scat deposition rates, (8) standardized track counts, (9) road-killed coyotes, and (10) the use of questionnaires and bounties. Benefits and drawbacks to each technique are discussed.

1993

Reports

Connolly, G. "Livestock Protection Collars in the United States, 1988-1993." Great Plains Wildlife Damage Control Workshop.

This report outlines the use of livestock protection collars from 1988-1993. These collars contain toxicants in a bladder that is attached by Velcro to the throat of a sheep or goat. This report outlines the popularity and use of these collars

1986

Journal Articles

Smith, R. H., D. N. Neff, and N. G. Woolsey. "Pronghorn response to coyote control - A benefit:cost analysis." *Wildlife Society Bulletin* 14(1986): 226-231.

Coyote predation of antelope on the Anderson Mesa in Arizona reduces fawn survival. This article determines the net benefits of coyote management prior to antelope fawning. The study examines both the costs and benefits of trapping and helicopter gunning of coyotes from 1977-1983. The number of coyotes taken per year ranged from 20 to 73. Costs from trapping per coyote ranged from $89 to $385, and costs per coyote for aerial hunting ranged from $235 to $296. Per coyote costs are compared to benefits derived from hunting costs ($63/day, 1983). Projected results indicate that net benefits range from $226,307 to $433,981 (1983 dollars).

Reports

Terrill, C. E. "Trends of Predator Losses of Sheep and Lambs from 1940 Through 1985." 12th Vertebrate Pest Conference.

This report outlines the percent losses of sheep and lambs overall and losses to predators in particular from 1940-1985. Data on the economic impacts on rural America are also given indicating that predation may play a part in the decline of the domestic sheep industry over this period. The report estimated the value of predator losses to range $13,470,000 - $89,865,000 per annum.

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