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An Economic Analysis of Predator Management in Wyoming

Final Report

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Contents

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Overview

The purpose of this report is to provide an understanding of the economics of predator management in Wyoming. To that end, the authors have researched the literature, talked to biologists, ranchers and state and local officials; analyzed costs and used computer models to simulate the economic the effects of predation and predator control. Many man-hours have been invested trying to understand the relationships between predators, livestock and wildlife from an economic perspective.

Our research shows that although predator control has a long history in Wyoming, it is very difficult to develop a complete picture of its economic contribution. Much data has been collected on the number of livestock killed by predator and the associated value, but very little on the effectiveness of management procedures. Only broad estimates exist on the number of predators, their densities and how they relate to their prey species. Furthermore, since our experience in the state is only with the affects of predation *and* predator management, it is difficult to say what the affects of predation would be *without* predator management. This is important because it implies that we do not have much to measure against and thus makes judging the relative economic benefits of predator management all the more difficult.

Our approach has been to find out what we know and what we don't know and make the best estimates within the limitations of existing knowledge. Some of the results show a wide range of values, such as those for the benefits of wildlife. This is the result of the wide range of input values available. This does not make them "wrong", but some parts of the range may make sense to use for one purpose and not for another. For example, the restitution value may make sense in the penalty phase of a court case, but perhaps not in an economic analysis. Readers should therefore use prudence when applying specific numbers from this report.

The report is organized into five sections. Section one lays the groundwork for the study by examining trends in Wyoming sheep and lamb predation for the period 1965 to 2006. The reason we focused on sheep and lamb predation is that this species has been the historical focus of Animal Damage Management Board (ADMB) activities and has suffered the most from predation. Also, more data is available on sheep than any other species. In researching this section, the authors also realized how much predation is attributed to coyotes. This realization led us to focus on coyotes in some of the subsequent sections. The authors recognize that other predators, such as eagles, mountain lions, bobcats, wolves and bears (both grizzly and black) are present in Wyoming and depredate livestock and wildlife, but it was more feasible to focus on the primary predator for which the ADMB spends the majority of its funding to control. Additionally, data constraints made it only feasible to focus on deer and antelope on the wildlife side.

Section two estimates the economic benefits and costs of predator control in Wyoming for both livestock and wildlife. Livestock numbers were easier to obtain, since government sources routinely track their numbers (sheep predation data has the longest record). Evaluating wildlife is much more difficult since data for wildlife either do not exist or exist only as estimates for a particular population in a specific geographic region. This made this part of the project particularly challenging and subject to the widest amount of variation in results.

Section three focuses on the financial effects of predator loss on a model ranch. We adapted a computer model of a cattle ranch to investigate the effects of three factors that might affect the profitability of a ranching operation as a result of predation. These factors include: increased death loss, reduced weaning weights and increased variable costs.

Section four estimates the economic impact of predator control on the Wyoming economy.

Section five is a literature review and annotated bibliography of predator control.

Also included in this report, as appendix A, is a paper published by one of our authors, Dr. Ben Rashford and two graduate students, which is an outgrowth of research for this project. His paper, *Economics of Predator Control to Protect Agriculture: The Unanswered Questions*, appeared in a recent edition of the online journal, “The Western Economic Forum”.

This report is also intended to serve as a baseline for understanding fiscal changes in predator management going forward from 2005, the year prior to a significant increase in Animal Damage Management Board (ADMB) funding. Future work might focus on better understanding the relationship between predator control methods and wildlife populations. Another area for future work is the expenditures by livestock producers to prevent predation on their herds. Work in both of these topics would provide a better understanding for future decision-making in predator control. As wildlife/livestock/predator interactions increase in importance and funding opportunities potentially become scarcer, understanding these relationships will be key to securing the resources for good stewardship of the state’s economy as well as its natural resources.

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 the series of the annual Wyoming Agricultural Statistics publications, we assembled a data base of sheep and lamb predation for a 42-year period from 1965 to 2006. This data base includes numbers 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 are 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 1.
Wyoming Sheep & Lamb Losses to Predators,
1965-2006

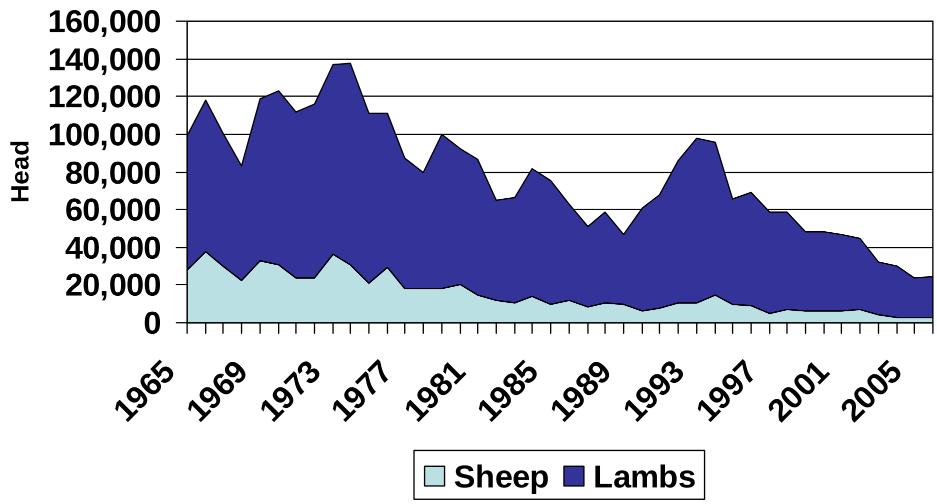
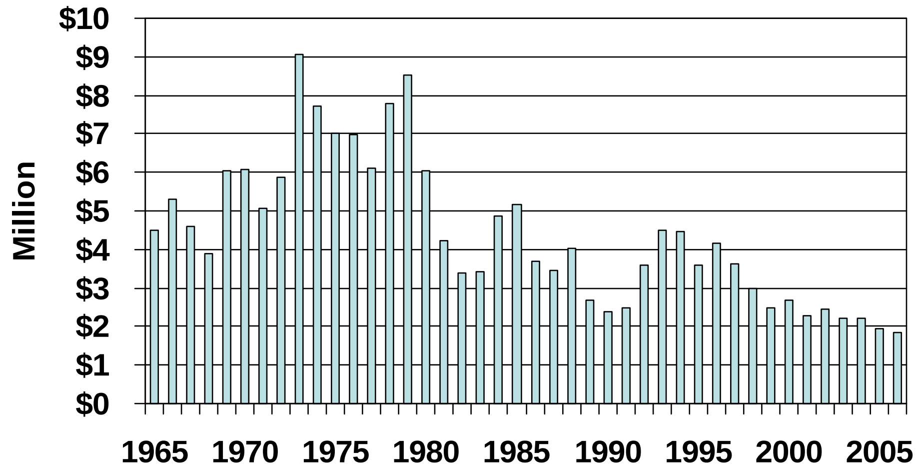


Figure 2 illustrates the market value of sheep and lambs lost to predators in Wyoming between 1965 and 2006. Over the 42-year time frame, the market value of sheep and lambs that were lost to predators was nearly $185.5 million in 2005 dollars (Table 2). The average annual loss was $4.4 million although 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.

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



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.

Figure 3.
Wyoming Breeding Sheep Inventory, 1965-2006

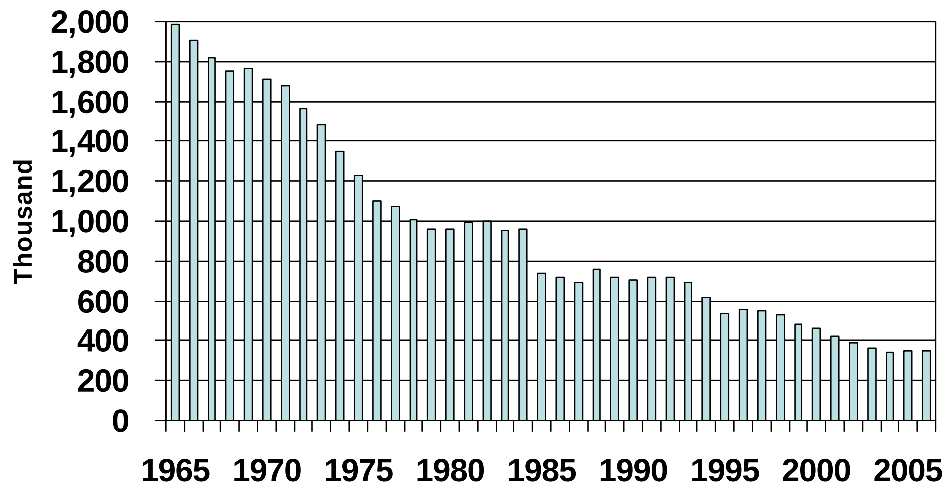
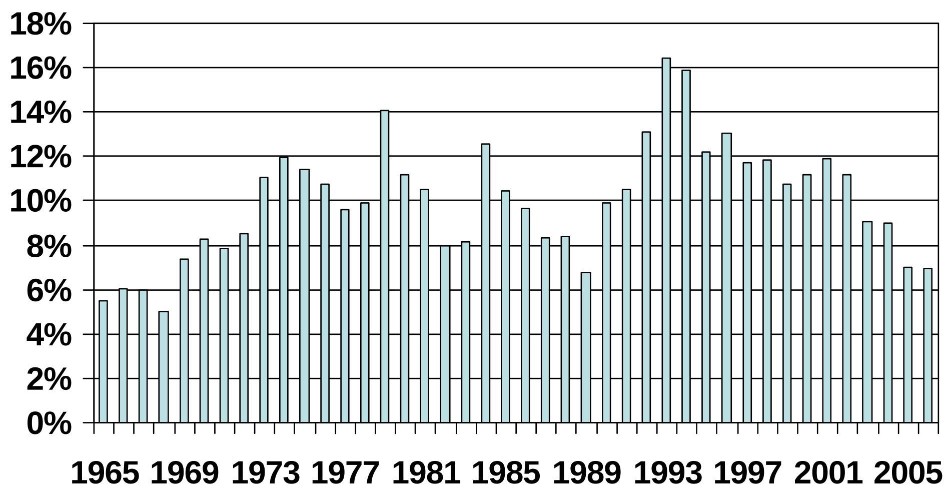


Figure 4.
Percent of Lambs Lost to Predators in Wyoming, 1965-2006



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 are 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).

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

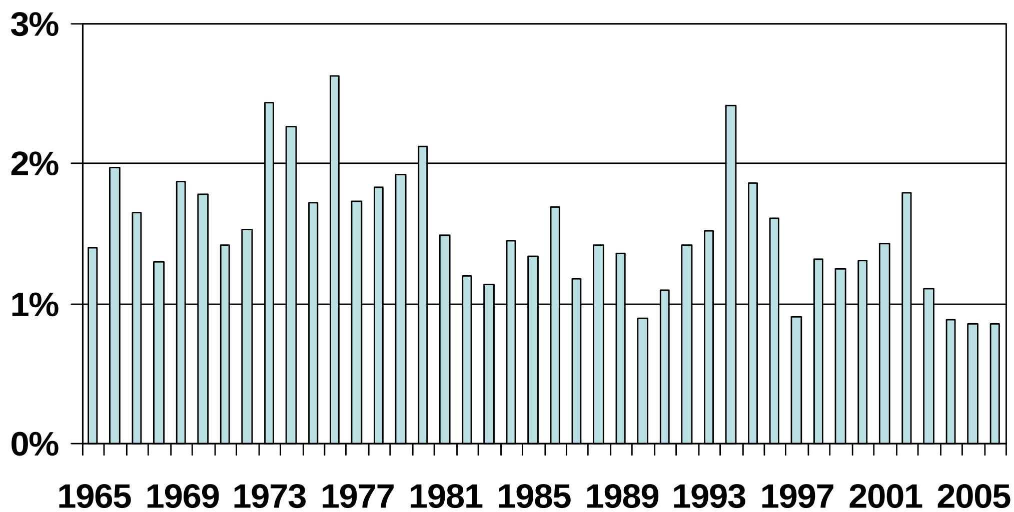
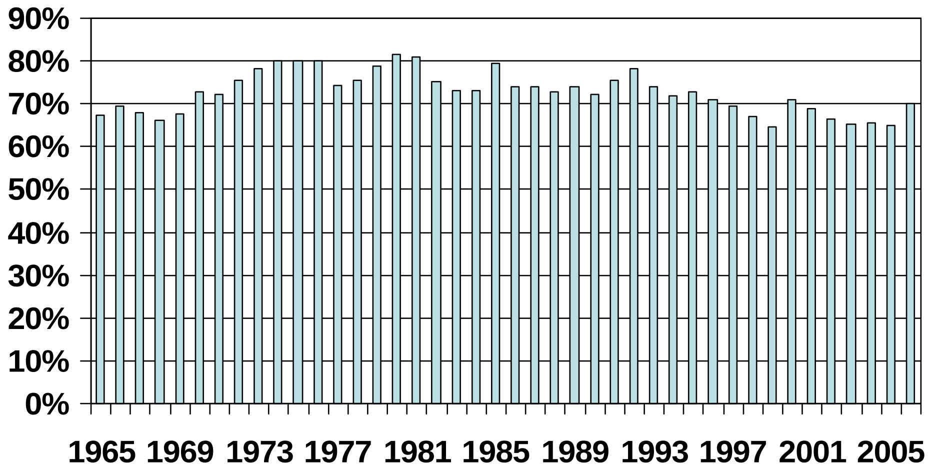


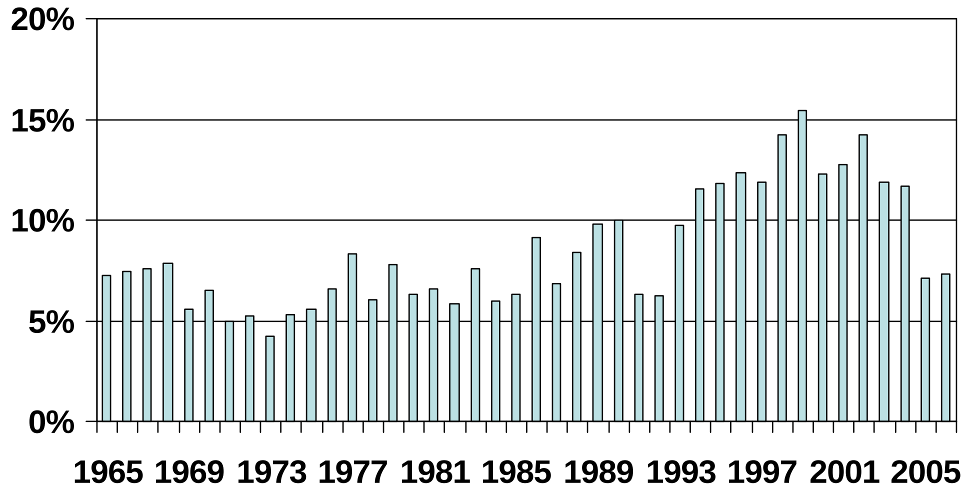
Figure 6.
Coyotes as a Percent of Predator Losses for Sheep and Lambs in Wyoming, 1965-2006



The pattern of predator losses for adult sheep is 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 to 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.

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



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

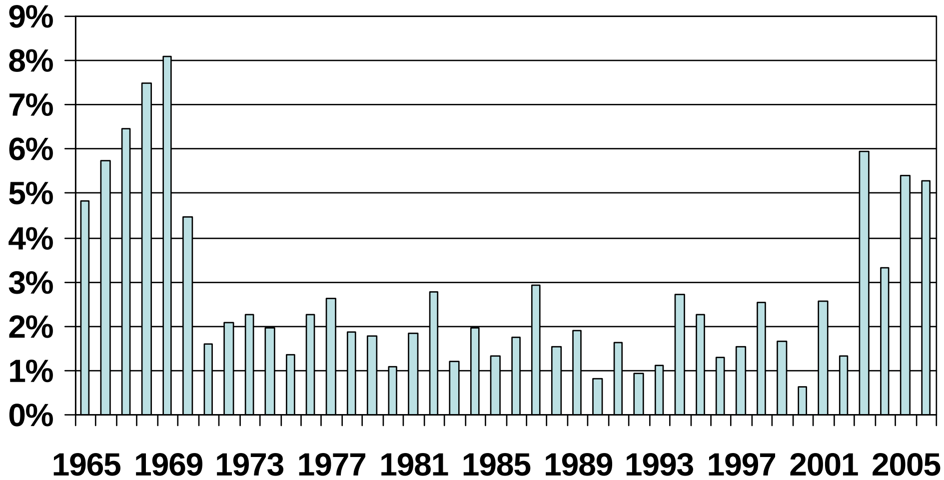


Figure 9.
Mountain Lions as a Percent of Predator Losses for Sheep and Lambs in Wyoming, 1986-2006

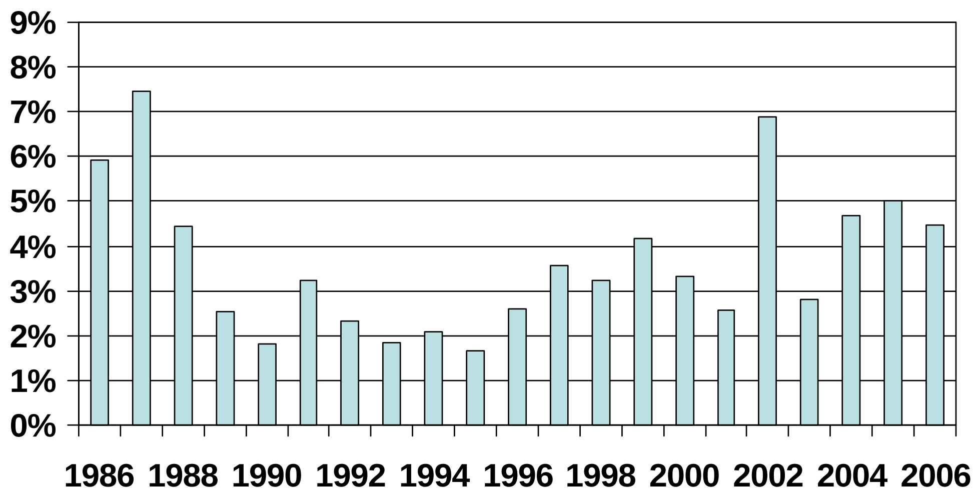


Figure 9 summarizes the relative importance of mountain lions as sheep and lamb predators. NASS only started estimating predator losses associated with mountain lions in 1986. As the figure shows, the percent of predator losses from mountain lions declined from 1986-1988 levels for several years, but 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 only considers 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 more complete picture of the predator situation in Wyoming.

Section II: 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 approximately $200,000 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).

The purpose of this section is to present estimates of the economic benefits and costs of predator management in Wyoming. The analysis considers the economic benefits to both livestock production and wildlife. The estimates of livestock and wildlife benefits are compared with the costs associated with predator management in the state to determine net benefits and the benefit-cost ratio for predator management in Wyoming.

Results of the analysis indicate that the estimated total economic benefits of predator management to livestock production and wildlife in Wyoming for 2005 ranged from $17.9 million to $203.5 million. The estimated costs of predator management in Wyoming for 2005 were $6.1 million. These results indicate an estimated net economic benefit from predator management to livestock production in Wyoming for 2005 of $11.8 to $197.5 million and a benefit-cost ratio of 2.9 to 33.4. The large range in benefit estimates was due to the alternative values used to value wildlife.

This analysis is based on the year 2005 because it is immediately prior to a significant increase in funding for predator management by the State of Wyoming. 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 economic benefits of predator management are difficult to determine because it requires estimation of the loss that was 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 more difficult to obtain. For this analysis, estimates from Bodenchuk (2000) on death loss with and without predator management are used as a basis for estimating economic benefits for livestock production. Bodenchuk (2000) 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 is utilized in the analysis because it considers multiple studies and includes studies in regions where livestock production is similar to that found in Wyoming.

In order to estimate the economic benefit of predator management to livestock production in Wyoming, predator loss estimates reported by Bodenchuk without predator management are compared with predator loss estimates with predator management based on the death losses reported in Wyoming Agricultural Statistics for 2005 (NASS). In addition to the benefits of predator management to livestock production, there can also be benefits of predator management to wildlife. In many cases the benefits represent specific efforts to protect wildlife from predators. Examples of this include various projects funded by the Wyoming Animal Damage Management Board where the focus is on wildlife protection. In other cases the benefits to wildlife may be the result of residual benefits from predator management for livestock protection. For example, Harrington and Conover (2007) found that preventative coyote removal for livestock protection was positively correlated with higher mule deer and pronghorn densities on seven study sites in northeastern Utah and northwestern Colorado

It is necessary to have some knowledge of the physical relationship between predator management and wildlife population numbers to estimate the benefits of predator management to wildlife. To determine this relationship the available literature on the relationship between predator management and wildlife populations was reviewed, particularly in terms of the relationship between coyotes and pronghorn antelope and mule deer. Biologists at the Wyoming Game and Fish Department and the University of Wyoming were also contacted to get their perspective. The general conclusion of this review was that there does not appear to be a consensus regarding the relationship between predator management and wildlife population numbers.

For example, Connolly (1978), in his review of effects of predation on ungulates, indicated that a selective review of the literature could reinforce almost any view on the role of predation. In his review, he found 31 studies that indicated predation was a limiting factor on ungulate populations and 27 studies indicating that predation was not a limiting factor on ungulate populations. Since Connolly’s review, biologists have continued to debate whether predation is a significant factor on ungulate populations (Messier 1991, Sinclair 1991, Skogland 1991, Boutin 1992, Van Ballenberghe and Ballard 1992). More recently, Gill (2001) notes that it is still unclear if predator control would increase mule deer and pronghorn densities or offspring survival because there have been few well-designed experiments on the subject.

Ballard et al (2001) indicated that the results of their review of 17 published studies concerning mule deer was equivocal; in some cases predator control appeared to be useful in improving deer populations and in some cases it was not. They also noted that some similarities from cases in which predator control appeared to be effective included: 1) predator control was implemented when the deer population was below habitat carrying capacity, 2) predation was identified as a limiting factor, 3) control efforts reduced predator populations enough to yield results (e.g., expected to be approximately 70 percent of a local coyote population), 4) control efforts were timed to be most effective (just prior to predator or prey reproduction), and 5) control occurred at a focused scale (generally, <1,000 km^2 or 386 mi^2).

Due to the lack of consensus regarding the relationship between predator management and wildlife populations, the estimates of benefits of predator management to wildlife in this study are based on a single case study of coyote predation on antelope in South-Central Wyoming (Merrell and Shwiff, 2003). This case study was selected because it is specific to Wyoming, is fairly recent, and had data on both the change in antelope and coyote populations. It should be noted, however, that there are inherent limitations in extrapolating from a single case study to statewide benefit estimates. In particular there is concern that the case study may not be representative of the entire state. Due to a lack of data, the analysis for wildlife is limited to the impact of coyote predation on antelope and mule deer.

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 four categories of predator management costs are considered, including: 1) expenditures by the Wyoming Office of Wildlife Services, 2) expenditures by State Government, 3) expenditure by County Predator Management Boards, and 4) expenditures by livestock producers. These cost estimates are 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 without predator management, a breakeven analysis is 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 range 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 are 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.

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)

The Bodenchuk's death loss estimates without predator management (third column of Table 1) and the reported Wyoming death loss estimates with predator management (the third column of Table 2) are compared to estimate the total economic benefit from predator management in Wyoming (Table 3). The second column of Table 3 contains 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 are derived by multiplying the total head numbers in the second column of Table 3 by the death loss rates in the third column of Table 1. Since there is no death loss estimate for cows in Table 1, cow death loss is assumed to be 14.3 percent of calf death loss. This assumption is 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 without predator management is over 97,000 head, with more than 50 percent of this loss being lambs.

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)

The death loss estimates without predator management are 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 is multiplied by the death loss rates in the third column of Table 2 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 28,000 head, with 75 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 69,000 head.

Table 3. Estimated Livestock Benefits from Predator Management

	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	3,500	18,700	$420.00	$7,854,000
Cows (1)	756,000	3,175	500	2,675	$1,113.00	$2,976,830
Sheep	350,000	19,600	3,000	16,600	$143.00	$2,373,800
Lambs	300,000	52,500	21,000	31,500	$72.60	$2,286,900
Total	**2,146,000**	**97,475**	**28,000**	**69,475**		**15,491,530**

(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

NASS (2006) market values per head by livestock type for Wyoming in 2005 are presented in column six of Table 3. These values are 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 indicate that the total benefit is nearly $15.5 million. Due to their higher market value more than 50 percent of the total benefit is from reduced calf losses. Market values are 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 the grazing season.

Table 4 summarizes the estimated economic benefits to antelope and mule deer from predator management in Wyoming. Data from the study of coyotes and antelope in South-Central Wyoming (Merrill and Shwiff, 2003) suggests that coyote/antelope elasticity is -0.229. This means that for a 75 percent decline in coyote population there would be a 17 percent increase in the antelope population. The Pre-Decisional Environmental Assessment (EA) for Predator Damage Management in Western Wyoming (USDA) indicates that there was an estimated coyote population in Wyoming of 58,748 in 1994-95. Data from the EA also indicates that excluding sports hunting 13,604 coyotes were removed from the population. This represents a 23.2 percent reduction in coyote numbers. Multiplying the 23.2 percent reduction in coyote numbers by the -0.229 coyote/antelope elasticity indicates that the reduction in coyote numbers

Table 4. Estimated Antelope & Mule Deer Benefits from Predator Management

	Antelope	Mule Deer
Coyote/Antelope-Mule Deer Relationship (Merrell)		
Elasticity	-0.229	-0.229
Coyote Management in Wyoming (ADC):		
Wyoming Coyote Population	58,748	58,748
Predator Management Take	13,604	13,604
Take Percentage	23.2%	23.2%
2005 Antelope & Mule Deer in Wyoming		
Population w/ Predator Management (2006 WG&F Annual Report)	515,294	500,256
Population w/o Predator Management	487,972	473,732
Increased Herd Size w/ Predator Management	27,322	26,524
Value of Increased Herd - Restitution Value		
Increased Herd w/ Predator Management	27,322	26,524
Restitution Value (2006 WG&F Annual Reports)	$3,000	$4,000
Total Economic Benefit	$81,965,244	$106,097,632
Value of Increased Herd - Economic Return Per Animal		
Increased Herd w/ Predator Management	27,322	26,524
Economic Return/Animal (2006 WG&F Annual Reports)	$376	$851
Total Economic Benefit	$10,272,977	$22,572,271
Value of Increased Herd - Economic Return Per Rec Day		
Rec Days w/ Predator Management (2006 WG&F Annual Report)	132,725	331,441
Rec Days w/o Predator Management (1)	123,189	317,516
Additional Rec Days with Predator Management	9,535	13,925
Economic Return/Rec Day (2006 WG&F Annual Reports)	$112.50	$97.66
Total Economic Benefit	$1,068,429	$1,359,946

(1) Rec days without predator management were based on the following regression equations:

Antelope Recreation Days = -47,113 + .349 * Antelope Population (R2 = .833)
(t=7.729)

Mule Deer Recreation Days = 68,807 + .525 * Mule Deer Population (R2 = .504)
(t=3.634)

should have resulted in a 5.3 percent increase in the antelope herd statewide. This suggests that in 2005 predator management increased the antelope herd size by 27,322 animals.

There is no market price for antelope. There are, however, a wide range of possible values that could be used for valuing the estimated increase in the antelope herd associated with predator management. For example, Shwiff and Merrell (2004) used four different values ($400, $1,500, $3,000, and $10,000). Three alternative values for antelope are used in this analysis. They are: 1) the Wyoming Game & Fish Department 's Restitution Value for 2005 ($3,000); 2) the Wyoming Game & Fish Department's Economic Return per Animal Estimate for 2005 ($376); and 3) the implied Wyoming Game & Fish Department's Economic Return per Recreation Day for 2005 ($112.50).

Applying the three alternative values for antelope to the estimated increase in the antelope herd size from predation management results in benefits estimates ranging from $1.1 million to $82.0 million (Table 4). The relationship between the antelope herd size and the number of recreation days is estimated based on a regression equation, derived by the authors, comparing herd size to recreation days for 1991 through 2007 (See footnote Table 4).

A similar procedure is used to estimate the economic benefits to mule deer from predator management in Wyoming. Due to a lack of data it is assumed that the coyote/mule deer elasticity is the same as the coyote/antelope elasticity. The three alternative values for mule deer are: 1) the Wyoming Game & Fish Department's Restitution Value for 2005 ($4,000); 2) the Wyoming Game & Fish Department's Economic Return per Animal Estimate for 2005 ($851); and 3) the implied Wyoming Game & Fish Department's Economic Return per Recreation Day for 2005 ($97.66). Mule deer values are less per recreation day due to the greater number of recreation days per harvested mule deer.

Applying the three alternative values for mule deer to the estimated increase in the mule deer herd size from predation management result in benefits estimates ranging from $1.4 million to $106.1 million (Table 4). Again, the relationship between the mule deer herd size and the number of recreation days is estimated based on a regression equation comparing herd size to recreation days for 1991 through 2007 (See footnote Table 4).

Four categories of predator management costs are considered to estimate the cost of predator management in Wyoming. The first category is expenditures by the Wyoming Office of the USDA-APHIS Wildlife Services. Information from Wildlife Services indicates that their total expenditures for predator management in Wyoming were $1.8 million in 2005 (Table 5). Wildlife Services also notes 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 is expenditures by State Government. In 2005 it is estimated that State Government spent $50,000 on predator management. This spending represents money allocated to County Predator Boards for predator management.

Table 5. Cost Analysis for Predator Management in Wyoming

	Amount	Percent
Federal Wildlife Services	$1,778,158	29.2%
State Government	$50,000	0.8%
Predator Fee Collections		
Gross Collections	$611,968	
Collection Fee @ 3%	$18,359	
Net Revenue	$593,609	9.7%
Producers (1)	$3,675,938	60.2%
Total Costs	**$6,097,705**	**100.0%**

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

A third category of cost information is 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. We assume that these funds are expended for predator management in the year that they are collected. The Wyoming Livestock Board data indicates that gross predator fee collection for 2005 totaled nearly $612,000 (Table 5). Allowing for the three percent collection fee, nearly $594,000 is assumed to be spent by County Predator Boards for predator management in Wyoming during 2005.

The final category of cost information is 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 indicates that a typical sheep producer in Wyoming engages in three non-lethal control methods of predator control. For cattle producers the most common methods of predator control are frequent checks (48 percent), culling (42 percent), and livestock carcass removal (33 percent). On average, the data indicate that a typical cattle producer in Wyoming engages 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 represents 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) is 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 uses 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).

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

Combining the four categories of predator management costs, we estimate that the total cost of predator management in Wyoming for 2005 was $6.1 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 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 and State Government.

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. Three separate benefit-cost estimates are presented based on the three alternative wildlife values considered in the analysis (Table 7). Estimated total benefits under the alternative valuations range from $17.9 million with the economic return per recreation day value to $203.5 million with the restitution value. This compares to an estimated cost for predator management of $6.1 million. Subtracting costs from benefits indicates an estimated net benefit from predator control of from $11.8 million to $197.5 million. The associated benefit-cost ratios range from $2.90 of benefits for $1.00 of cost to $33.40 dollars of benefits for $1.00 of cost.

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

	Big Game Restitution Value	Big Game Economic Return Per Animal	Big Game Economic Return Per Rec Day
Estimated Benefits:			
Calves	$7,854,000	$7,854,000	$7,854,000
Cows	$2,976,830	$2,976,830	$2,976,830
Sheep	$2,373,800	$2,373,800	$2,373,800
Lambs	$2,286,900	$2,286,900	$2,286,900
Antelope	$81,965,244	$10,272,977	$1,068,429
Mule Deer	$106,097,632	$22,572,271	$1,359,946
Total Benefits	$203,554,406	$48,336,778	$17,919,905
Estimated Costs:			
U.S. Wildlife Services	$1,778,158	$1,778,158	$1,778,158
State Government	$50,000	$50,000	$50,000
County Predator Boards	$593,609	$593,609	$593,609
Livestock Producers	$3,675,938	$3,675,938	$3,675,938
Total Costs	$6,097,705	$6,097,705	$6,097,705
Net Benefits	$197,456,701	$42,239,073	$11,822,200
Benefit-Cost Ratio	**33.4**	**7.9**	**2.9**

As previously mentioned, there is some uncertainty regarding the relationship between predator management and wildlife populations. Due to this uncertainty a breakeven analysis is conducted to determine the minimum amount of a predation management benefits needed for the management effort to be cost effective. The second column of Table 8 indicates the percent of the total herd that is estimated to be saved by predator management in the benefit-cost analysis. The values range from 0.035 percent of the cow herd to 10.5 percent of total lambs. The third column of Table 8 indicates what the percent of death loss for the total herd would have to be reduced to in order for predator management to be cost effective, if the economic returns per recreation day are used to value wildlife. Similar values are presented for the breakeven reduction in death loss if the economic returns per animal or restitution value are used to value wildlife. In general, the reduction in death loss would only have to be one-third of the estimated values for predator management to be cost effective using the economic returns per recreation day values. Using the economic returns per animal values, the reduction in death loss would only have to be one-eighth of the estimated values in order for predator management to be cost effective. For restitution values, the reduction in death loss would only have to be three percent of the estimated values in order for predator management to be cost effective.

Table 8. Breakeven Analysis for Predator Management in Wyoming

	Estimated Saved From PM	Breakeven Rec Day Values	Breakeven Per Animal Values	Breakeven Restitution Values
Calves	2.53%	0.86%	0.32%	0.08%
Cows	0.35%	0.12%	0.04%	0.01%
Sheep	4.74%	1.61%	0.60%	0.14%
Lambs	10.50%	3.57%	1.32%	0.31%
Antelope	5.30%	1.80%	0.67%	0.16%
Mule Deer	5.30%	1.80%	0.67%	0.16%

Summary and Conclusion

Estimates of the economic benefit of predator management in Wyoming indicate that total benefits range from $17.9 million to $203.5 million in 2005. The large range in benefits result from the alternative values used to estimate the economic value of wildlife. From a cost perspective, the total cost of the predator management program in Wyoming for 2005 is estimated to be $6.1 million. These costs include expenditures by Wildlife Services, state government, county predator boards, and livestock producers to mange predation.

Based on the $17.9 million to $203.5 million range in total benefits from predator management, the net benefit of predator management is estimated to be from $11.8 million to $197.5 million and the benefit-cost ratio is from $2.90 to $33.40 of benefits per $1.00 of costs.

Due to the uncertainty associated with the relationship between predator management and wildlife populations, a breakeven analysis is conducted to determine the minimum amount of predator management benefits needed for the effort to be cost effective. The reduction in death loss would only have to be one-third of the estimate values for predator management to be cost effective using the economic returns per recreation day values. Using the economic returns per animal values, the reduction in death loss would only have to be one-eighth of the estimate values in order for predator management to be cost effective. For restitution values, the reduction in death loss would only have to be 3.0 percent of the estimated values in order for predator management to be cost effective.

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 can potentially reduce ranch profitability through three mechanisms: 1) increased livestock death loss, 2) reduced livestock weaning weights due to stress, and 3) increased ranch labor and management costs. The following section analyzes each issue separately using the same base model.

Methods

We use a computerized ranch model to simulate the economic effects of increased death loss, decreased weaning weights and increased variable costs. The simulation model uses a multi-year 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 grazing use given a defined cattle price scenario. In the process, the profit-maximizing livestock sales and ranch income are 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 a randomized set of 100 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 alternative cattle price scenarios (Tanaka et al. 2007).

With assistance from the original authors, the ranch modeling framework discussed above was modified into the Western Wyoming Grazing Model (WWGM) to reflect the production characteristics of ranching operations in Western Wyoming. This modification is based on previous analysis's in Fremont and Park Counties (Taylor et al. 2004, 2005). Once the model was operational, changes in death loss, weaning weights, and variable costs relative to the base line were made by changing parameters in the model and re-running the 40-year horizon.

Increased death loss

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. 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 grizzly and an average of 5.7 percent with both grizzly 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 scenario 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.

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 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 were calves. In this scenario, the death loss ratios for calves are changed in four different runs to show the effects of increased death loss on ranch productivity and profits. The cause of the death loss is not specified in the model and could come from any source. The baseline run 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 runs simulate alternative predation rates by increasing the death loss ratio in two percent increments to 10 percent.

Reduced weaning weights

We also use the WWGM to investigate the effects of reduced weaning weight. Calves are the end result of the ranch's year-long production process. The ranch operator has significant resources invested in calves and thus most ranch profit is derived from the sale of these animals. As an alternative, the rancher can also sell hay. However, since the there is less profit in hay, the (model) ranch would prefer to sell calves.

Weaning weights are important to ranch profitability. Higher weaning weights mean more gross income to the ranch. Researchers have suggested a link between predation, or the stress caused by the presence of predators, on weaning weights (Clark, 2007). No definitive analysis is known to exist. Anecdotally, a number of producers have also suggested that the stress of the presence of predators can have an effect calf weaning weights. In the WWGM, we model this effect by reducing the sale weight of calves.

Table 9 shows the weaning weights of calves used in the model. The 'base' weights are the average weights of steer and heifer calves across the base model run. The columns to the right of the base column are reductions in weaning weight by the percent indicated in the column heading.

Table 9. Sale weights (pounds) used in the computer simulation.

	Base	1 pct	3 pct	5 pct	10 pct
Steer calves	440	436	427	418	396
Heifer calves	390	386	378	371	351

Increased variable costs

Ranching operations face two types of costs, variable and fixed. Variable costs are the costs that increase with each additional unit of production. In the case of ranching, variable costs include items such as hay and other feeds, veterinary costs, fuel, equipment repair, trucking and labor. Fixed costs are costs that do not vary with the level of production, such as taxes, insurance, depreciation and loan payments.

In addition to death loss and decreased weaning weights, ranch profitability could be affected by predators through increased variable costs for labor and management. Ranchers would likely face increased herding costs, possibly having to add additional herders if conditions warrant. Also, increased management in the form of documentation of predatory incidents, added veterinary costs, additional mileage to check on animals and potentially costs to move animals away from predator range/habitat locations.

We use the WWGM to investigate the effects of increased variable costs, increasing the costs of using different grazing land types. The model incorporates labor and management and other variable costs into the per animal unit month (AUM) cost for each grazing land type used in the model. So increasing grazing cost can be used as a proxy for increased variable costs. Grazing costs were increased 5 percent and 10 percent, in the model to evaluate the effects on profitability in the model ranch.

Table 10 lists the grazing land costs, and the increases used in the increased variable cost scenario of the WWGM to model the affect of increased variable cost on profitability in the model ranch.

Table 10. Range of specified increases in variable costs, as expressed in dollars per AUM, by land type.

	Base	**5 pct**	**10 pct**
BLM	$7.19	$7.55	$7.91
USFS	$9.46	$9.93	$10.41
State	$10.79	$11.33	$11.87
Private lease	$13.25	$13.91	$14.58
Deeded range	$3.25	$3.41	$3.58

Results

Increased Death Loss

Table 11 outlines the results for the four runs in the death loss scenario with gross revenue, net livestock returns, ranch profits, percent of years with negative profits, cows, calves and tons of hay sold. In the base model (4% death loss), the ranch has gross revenue of $244,163; net livestock returns totaled $65,172 and ranch profits of $27,822. There are 610 bred cows (including both brood cows and first calf heifers) producing 569 calves (accounting for conception rates and death loss). The ranch also sells 169 tons of hay.

As death loss increases, 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, thereby reducing 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.

Table 11. Simulation model results for increased death loss of calves.

Death Loss	**Gross revenue**	**Net livestock returns**	**Ranch profits**	**Percent negative years**	**Cow herd**	**Calves**	**Tons of hay sold**
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

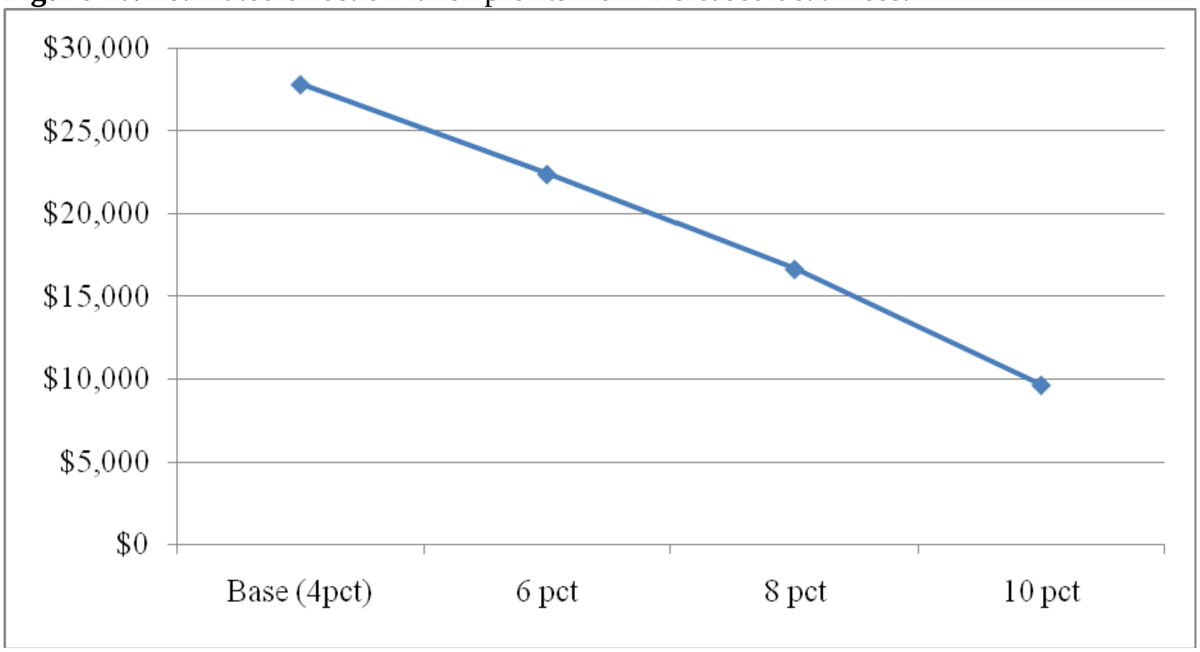
When calf death loss is adjusted to 8 percent, gross returns decrease by 6 percent from the base case run, while the number of mother cows is reduced by 3.6 percent to 588. Hay sales increase by 21 percent to 184 tons. Again, in order to maximize profit, the model is adjusting by slightly reducing herd 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 run.

Ranch profits decline by over 65 percent in the 10 percent calf death loss model run. At this level of death loss, the model has optimized by increasing hay sales by 41 percent over the base run 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 run, but more heifer calves are retained, instead of being sold, increasing variable costs (raising cows) instead of generating profits.

The overall trend in ranch profits across the runs 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 (Table 11). In the base run, 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 an average of 4 negative years in 10 for the operation. Increased income variability increases stress on management and increases the chance of business insolvency.

Figure 10. Estimated effect on ranch profits from increased death loss.



Reduced Weaning Weights

Table 12 and Figure 11 show the results from the WWGM for the reduced weaning weights scenario. ‘Net livestock’ are net livestock returns, before fixed costs. ‘Cow herd’ is all cows that have calved. This includes both brood cows and first calf heifers.

Profit in the model ranch is shown to be $27,822 in the base run. With a 1 percent reduction in average weaning weights (4 lbs), profits decline by over $2,000 or 7.5 percent. With a 5 percent reduction (22 lbs), ranch profits decline by over $10,800 or 39 percent. When weaning weights are reduced by 10 percent (44 lbs for steers, 39 lbs for heifers), profit is negative (a loss). This is because fixed costs are the same regardless of herd size. And yet the ranch is still selling 523 calves and 252 tons of hay. Smaller, lighter calves have erased all profits.

Figure 11 shows how profitability declines steadily through a 5 percent reduction in weaning weight and then drops off precipitously to 10 percent where profitability becomes negative. The percent of negative years in the scenario is further indication of reduced profitability under this condition. The percent of negative years in the base run is 32 percent, which means that on average, the model ranch has a loss one in three years. The model runs for one, three and five percent reductions in weaning weight show a steady, but moderate increase in the percent of negative years. However, after five percent, the rate of increase and thus the drop off in profitability picks up considerably. At a 10 percent reduction in average weaning weight, the ranch has a 51 percent chance of incurring a loss in any given year. This is a 20 percent increase over the base run and causes serious doubt on the viability of the operation without additional income sources.

Table 12. WWGM results for reduced weaning weights.

	Net livestock returns	**Ranch profit**	**Percent negative years**	**Cow herd**	**Calves**	**Hay sold (tons)**
Base	$65,172	$27,822	32%	610	569	169
1 pct reduction	$63,083	$25,733	33%	607	567	200
3 pct reduction	$58,800	$21,450	36%	600	560	185
5 pct reduction	$54,308	$16,958	39%	591	552	200
10 pct reduction	$36,622	-$727	51%	559	523	252
Percent change from base model						
1 pct reduction	-3.2	-7.5	1%	-0.5	-0.4	18.3
3 pct reduction	-9.8	-22.9	4%	-1.6	-1.6	9.5
5 pct reduction	-16.7	-39.0	7%	-3.1	-3.0	18.3
10 pct reduction	-43.8	-102.6	20%	-8.4	-8.1	49.1

Figure 11. Ranch profits with reduced weaning weights.

Increased Variable Costs

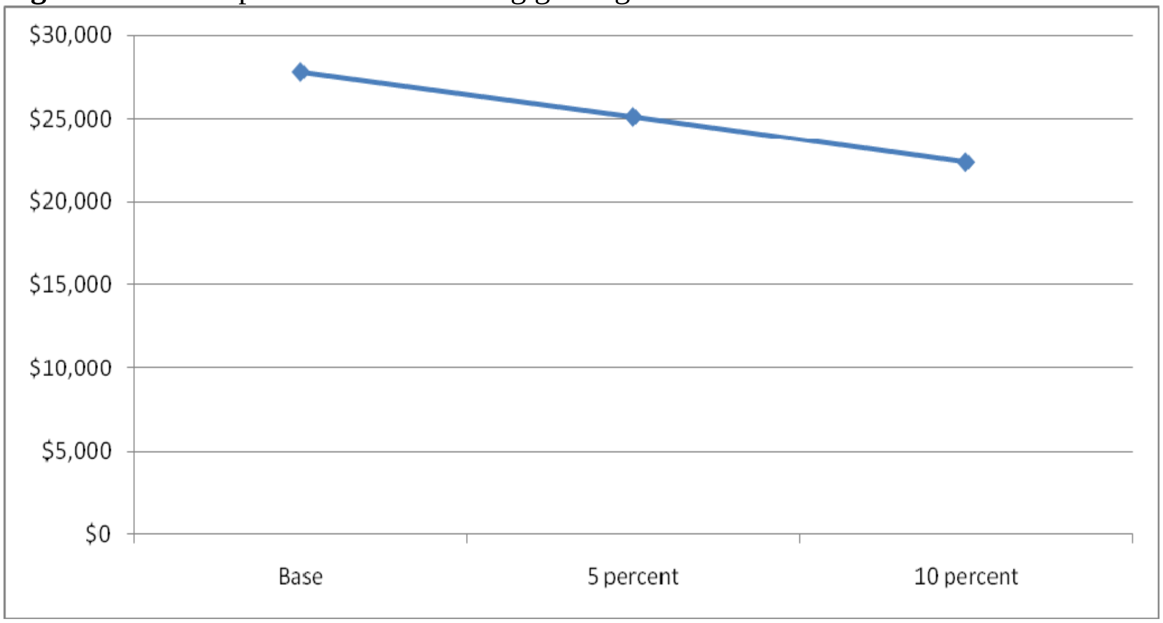
The results of the scenario modeling the effects of increased variable costs are shown in Table 13 and Figure 12. Net livestock returns decline over the range of results by 8.4 percent from $65,172 to $59,728. Ranch profits decline by 19.6 percent, from $27,822 to $22,378. The cow herd declines by 2.3 percent from 610 cows to 596 cows. Calf numbers reflect the decline in cow numbers, declining 2.1 percent. Hay sales increase by 13.6 percent from 169 tons to 192 tons.

Table 13. WWGM results for increased variable costs.

	Net livestock returns	Ranch profits	Percent negative years	Cow herd	Calves	Hay sold (tons)
Base	$65,172	$27,822	32%	610	569	169
5 pct increase	$62,496	$25,146	33%	604	564	179
10 pct increase	$59,728	$22,378	36%	596	557	192
Percent change from base model						
5 pct increase	-4.1	-9.6	1.5	-1.0	-0.9	5.9
10 pct increase	-8.4	-19.6	3.7	-2.3	-2.1	13.6

The percent of negative years increases only slightly over the model runs in this scenario. This shows that although profitability suffers with increased grazing costs, the ranch may remain viable through a 10 percent increase even though the percent of negative years increases by 3.7 percent from 32 percent to 36 percent.

Figure 12. Ranch profits with increasing grazing cost.

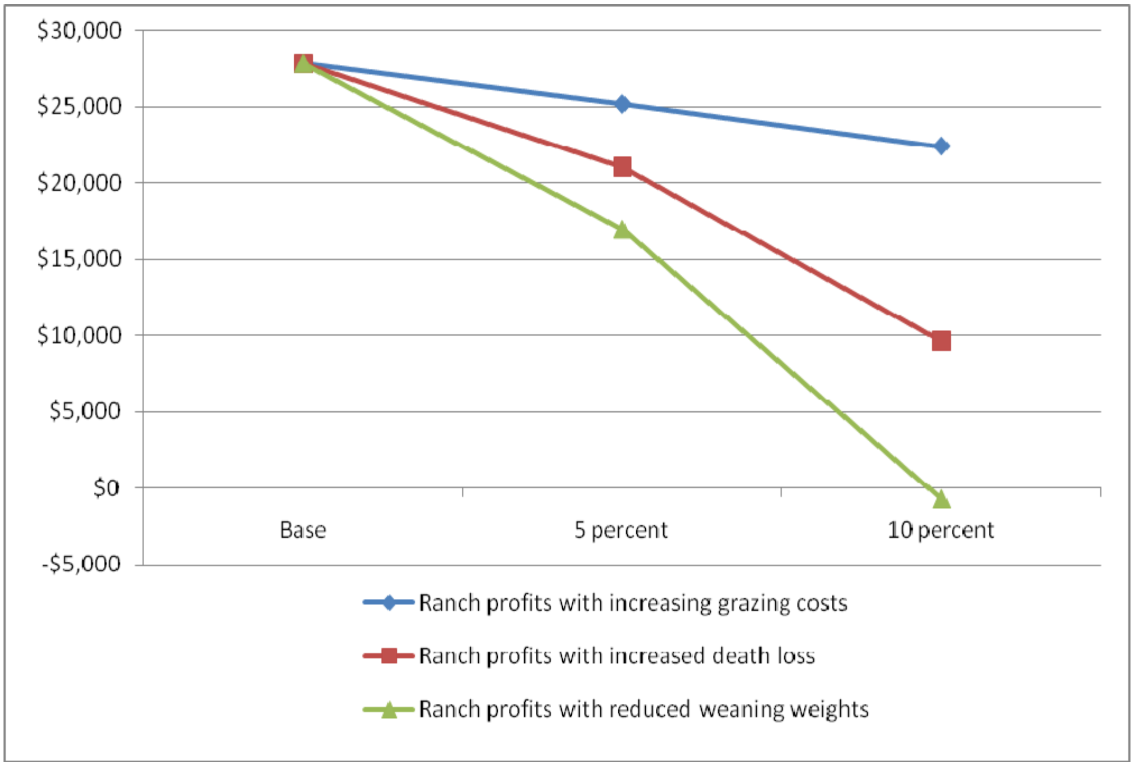


Conclusions

Figure 13 shows these three modeling scenarios in a single graph. This picture shows the range of sensitivities to profitability of the different effects that producers might encounter as a result of predation, or the presence of predators nearby to their ranching operations. Our model shows that of the three scenarios, increasing grazing costs (as a proxy for increased variable costs) has the least affect on profitability. The model responds to the increased variable costs by decreasing herd size and increasing hay sales as variable costs rise. The results are similar to results seen for increases in death loss reported earlier, but not as great as those reported for decreased weaning weight. This is likely due to the fact that there is some flexibility in the model for grazing land use. The model will use the cheaper land first and only as much of the more expensive land as is required.

Increased death loss takes a larger toll on profitability because it erodes the ranch’s core profit center, calves. So even though the ranch maximizes production of calves at sufficient weight, the removal of some calves through predation decreases profitability even as fixed costs for the operation remain the same. The producer must cover these fixed costs in order to stay in business in the long-term. Ranching typically involves high fixed costs in its asset base, (e.g. land and cattle). 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. With a 10 percent death loss of calves, the long term viability of the operation comes into question.

Figure 13. Ranch profits with different predator effect scenarios.



The reduced weaning weight scenario shows how a producer interested in maximizing profits might react to reduced weaning weights in calves. As weaning weights decline, hay sales are substituted for some of the calves. Herd size is reduced slightly, but the producer continues to maximize the number of calves raised, while substituting some hay sales. Yet as weaning weights are reduced further, the profitability of hay versus calves starts to shift more toward hay. Even when profits are negative, substantial numbers of calves are still sold. This means that maintaining healthy weaning weights is critical to the operation.

Of the three scenarios, reduced weaning weights have the most effect on profitability. This is likely due to the fact that reduced weaning weights affect all calves and thus the product itself is affected in total. That is, unlike death loss, were the calves are still profitable and only quantity is reduced. Reduced weaning weights means calves are less profitable in general and thus the shift away from calves towards hay sales is quicker. Yet just as in the death loss scenario, fixed costs remain the same and so the ranch has to contend with lower profits, while still supporting the infrastructure costs.

Figure 13 also raises the question of whether or not these effects could potentially be cumulative or dynamically interactive. That is, could a producer have increased death loss, lower weaning rates and increased labor and management costs at the same time, and how the effects of one might be translated to the other two? Intuitively one would answer ‘yes’, but at this stage, without more definitive data, the relationship between each of these factors is highly speculative. We have therefore chosen to present these results separately. Further research would be required to determine the nature of these interactions and their effects.

Section IV: Economic Impact of Predator Control

There are generally two types of economic analysis that can be conducted to evaluate natural resource policy issues such as predator management. One is benefit-cost analysis and the other is regional economic impact analysis. The benefit-cost analysis for predator management in Wyoming is presented in Section 2 of this report. This section considers the regional economic impact of predator management in Wyoming. The distinguishing characteristic of a regional economic impact analysis is that it tries to answer questions about the distribution of economic gains and losses. For a given change in the economic activity in a region, how much employment and income do individual sectors of the region's economy gain or lose? Thus, a regional economic impact analysis addresses a different question than does a benefit-cost analysis, which deals with the question of efficiency of a natural resource policy action, i.e. do total benefits exceed total costs. The distribution of economic benefits and costs is not usually considered in benefit-cost studies.

Economic impact analysis estimates how a region's overall economy will change as a result of a change in one aspect of the economic activity in the region. It does this by tracing the spending patterns of individual sectors through the economy and measuring the cumulative effects of that spending. Economic impact analysis considers both the direct effects in the individual sectors where the change occurs and the secondary effects in all the other sectors of the region's economy that are linked to the impacted sectors. These linkages represent re-spending that result from purchases by one sector from other sectors and purchases by employees of one sector from other sectors. Economic impacts are typically measured in terms of the change in employment and income.

This analysis considers two important industries in Wyoming that are directly affected by predators. One is livestock production and the other is big game hunting. In this section the benefit estimates from the benefit-cost analysis in Section 2 are used to estimate the economic impact of predator management in Wyoming. A 2006 IMPLAN model of the Wyoming economy is used to estimate the direct and secondary employment and income gained from the management of predators in the state based on the benefit estimates from Section 2. IMPLAN is a nationwide economic modeling system originally developed by the U.S. Forest Service that is capable of providing economic models down to the county and even zip code level. It is now supported by the Minnesota IMPLAN Group (MIG). The objective of this section of the report is to estimate the economic impact of predator management in Wyoming for livestock production and for big game hunting in terms of pronghorn antelope and mule deer.

For livestock production the economic impact of predator management is based on the $15.5 million of production that is estimated to be saved through predator management in Section 2. Without predator management it is assumed that the value of this production would be lost to the state's economy. Table 14 indicates how the $15.5 million of revenues would be distributed among the various sectors of the Wyoming economy. This distribution is based on cattle and sheep budgets from the University of Idaho's 2006 Idaho Livestock Costs and Returns Estimates (Rimbey et al, 2006 and Smathers et al 2006).

For pronghorn antelope and mule deer hunting the economic impact of predator management is based on the additional estimated hunting expenditures that result from predator management in Section 2. Without predator management it is assumed that these expenditures would be lost to the state's economy. Since the analysis was focused on economic value of big game and not the restitution value of illegally killed game, only the economic returns per animal and per recreation day are considered in the economic impact analysis. In addition, because economic impact analysis is based on new revenues to a region's economy and not a redistribution of existing revenues within the region, only non-resident expenditures are typically considered in economic impact analysis. The 2006 Annual Report for the Wyoming Game and Fish Department indicates that 63 percent of pronghorn antelope hunter expenditures in 2005 were by non-residents and that 38 percent of mule deer hunter expenditures were by non-residents. Based on these ratios, total hunting expenditures for pronghorn antelope and mule deer by non-residents resulting from predator management are estimated to be $15.0 million with the economic returns per animal values (high scenario) and $1.2 million with the economic returns per recreation day value (low scenario). Table 15 shows how the non-resident expenditures are distributed among the various sectors of the Wyoming economy under both the high and low expenditure scenarios. The distribution is based on a hunting expenditure survey for Wyoming by Responsive Management (2004).

Table 16 summarizes the economic impact of predator management in Wyoming estimated by the IMPLAN model. Total employment (direct and secondary) resulting from predator management is estimated to range from 408 to 624 jobs depending on which economic returns are considered for hunting. Much of this employment is in the Ag, Forestry, Fishing, & Hunting; Accommodations & Food Services; Retail Trade; Arts, Entertainment, & Recreation; and Other Services Sectors. Total labor earnings (direct and secondary) resulting from predator management is estimated to range from $11.5 to $17.3 million depending on which economic returns were considered for hunting. Much of these earnings are in the Ag, Forestry, Fishing, & Hunting; Accommodations & Food Services; Retail Trade; Government; and Health & Social Services Sectors. Average earnings per job with the high economic returns for hunting were $27,662 and $28,348 with the low economic returns for hunting. These results suggest that predator management in Wyoming makes an important contribution to the Wyoming economy through increased livestock production and increased hunting expenditures by non-residents.

Table 14. Additional Revenue for Livestock Production from Predator Management

Sector	Amount	Percent
Grain Farming	$626,631	4.0%
Hay and Forage	$3,172,969	20.5%
Replacement Livestock	$309,769	2.0%
Ag Support Activities	$91,597	0.6%
Grazing Leases	$718,239	4.6%
Crop Aftermath	$389,504	2.5%
Protein Supplement & Salt	$349,470	2.3%
Trucking	$89,196	0.6%
Marketing Fees	$64,286	0.4%
Veterinary Medicine	$307,452	2.0%
Vehicles (Fuel, Repair)	$198,532	1.3%
Equipment (Repair)	$242,791	1.6%
Housing and Improvement (Repair)	$256,594	1.7%
Replacement Cattle	$316,529	2.0%
Dog Food	$186,526	1.2%
Interest on Operating Capital	$149,871	1.0%
Overhead	$218,511	1.4%
Grazing Organizations	$122,707	0.8%
Intermediate Payments	$7,811,173	50.4%
Employee Compensation	$1,728,812	11.2%
Proprietor Labor	$672,693	4.3%
Proprietor Risk and Management	$3,577,848	23.1%
Other Property Income	$1,648,180	10.6%
Taxes	$52,824	0.3%
Final Payments	$7,680,357	49.6%
Total Payments	$15,491,530	100.0%

Labor Assumptions:

Direct Employment	**231.3**
Total Labor Earnings	**$5,979,353**
Average Earning Per Job	**$25,852**

Table 15. Combined Additional Expenditures for Hunting from Predator Management

	NR Antelope High	NR Deer High	NR Combined High	NR Antelope Low	NR Deer Low	NR Combined Low
Major Equipment	$179,895	$373,361	$553,256	$18,710	$22,494	$41,204
Minor Equipment	$183,743	$242,156	$425,899	$19,110	$14,590	$33,700
Gasoline	$880,219	$1,086,394	$1,966,614	$91,546	$65,454	$157,000
Motor Vehicle Repairs	$159,178	$101,047	$260,225	$16,555	$6,088	$22,643
Local Transportation	$119,480	$151,365	$270,845	$12,426	$9,120	$21,546
Groceries & Liquor	$464,865	$788,780	$1,253,645	$48,348	$47,523	$95,871
Lodging	$1,044,424	$1,388,130	$2,432,554	$108,624	$83,633	$192,257
Food & Drink	$945,338	$1,281,743	$2,227,082	$98,319	$77,223	$175,542
Entertainment	$53,908	$76,845	$130,753	$5,607	$4,630	$10,236
Other Licenses	$394,190	$334,303	$728,493	$40,997	$20,141	$61,139
Access Fees	$433,275	$861,217	$1,294,491	$45,062	$51,887	$96,949
Outfitter & Guides	$167,228	$403,799	$571,027	$17,392	$24,328	$41,721
Campground Fees	$31,954	$39,384	$17,835	$3,323	$2,373	$1,424
Meat Processing	$548,341	$586,154	$1,134,495	$57,030	$35,315	$92,344
Taxidermy	$503,684	$249,947	$753,630	$52,385	$15,059	$67,444
Gifts & Souvenirs	$362,407	$548,185	$910,592	$37,692	$33,027	$70,719
Miscellaneous	$51,081	$34,975	$86,056	$5,313	$2,107	$7,420
Total	**$6,523,212**	**$8,547,784**	**$15,017,492**	**$678,439**	**$514,991**	**$1,189,158**

Table 16. Economic Impact from Predator Management in Wyoming

Sector	Total Employment w/High Hunting	Total Employment w/Low Hunting	Total Earnings w/High Hunting	Total Earnings w/Low Hunting
Ag, Forestry, Fishing & Hunting	293.5	288.5	$8,043,332	$7,977,368
Mining	2.0	0.9	$305,081	$133,683
Utilities	1.6	0.9	$146,844	$82,141
Construction	3.6	2.7	$163,188	$119,399
Manufacturing	6.0	1.7	$179,165	$75,561
Wholesale Trade	10.5	4.0	$623,496	$235,796
Transportation & Warehousing	8.0	4.3	$327,347	$178,361
Retail Trade	66.8	23.0	$1,321,281	$502,349
Information	3.3	1.5	$122,285	$56,470
Finance & Insurance	6.6	4.2	$253,748	$163,807
Real Estate & Rentals	14.6	9.3	$426,565	$278,664
Professional Services	14.8	11.3	$489,668	$351,250
Management of Companies	0.6	0.2	$45,368	$15,413
Administrative & Waste Services	7.6	3.5	$161,926	$75,053
Educational Services	1.6	1.0	$28,656	$18,391
Health & Social Services	19.4	13.1	$756,250	$505,640
Arts, Entertainment, Recreation	25.4	3.7	$689,447	$93,599
Accommodations & Food Services	99.5	17.3	$1,914,290	$299,294
Other Services	24.7	14.2	$485,476	$289,392
Government	14.0	2.3	$780,738	$103,149
Total	**624.1**	**407.6**	**$17,264,151**	**$11,554,70**
Average Earnings Per Job			**$27,662**	**$28,348**

Section V: Literature Review: Economics of Predator Control

Introduction

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 the long history of formal predator control, there are relatively few rigorous economic analyses of predator control. In a 1972 report the Department of the Interior's Advisory Council on Predator Control stated:

> "Control decisions are still based on the assumption of benefit rather than on proof of need. Bureau officials have frequently given lip services to the need for in-depth socio-economic studies, but no firm effort has been made to obtain Congressional appropriations to accompany this…The few federal efforts at economic evaluation of predator control continue to be based on biased sources; and it is likely that this bias has increased owing to the pressures the control programs have come under in recent years. As a result, these superficial studies are of limited value (Cain, et al., 1972: pp 12, 25) [1]."

While much research has been done since this statement, there are still large gaps in our understanding of the economics of predator control.

The objective of this literature review is to summarize existing research to inform both current policy and to stimulate future research. We begin by briefly reviewing several economic models amendable to the analysis of predator control. This review is followed by a comprehensive summary and annotated bibliography of the existing literature.

Review of Economic Models for the Analysis of Predator Control

Several standard economic models are well suited to the analysis of predator control. The standard models discussed here are capable of addressing slightly different questions, have different data requirements and scales of analysis, and often require dramatically different levels of sophistication to perform. Despite what often appear to be significant differences, almost all economic models attempt to identify "efficient" allocations of resources. Efficiency in its simplest form implies that for any use of resources, the greatest gain possible is attained. Specific definitions of efficiency can differ across models and are often not clearly stated by authors. Stated or not, some efficiency criterion is generally implicit in economic analyses of predator control. The non-economist is advised to keep the concept of efficiency in mind when reviewing economic literature because each author's specific notion of efficiency typically drives the research questions asked and the research design.

[1] Cain, S. A., et al. "Predator Control - 1971." Institute for Environmental Quality, January, 1972.

We briefly review four commonly applied, or readily applicable, economic models for analyzing predator control questions: cost-benefit analysis, cost-effectiveness analysis, cost-utility analysis and budget analysis. The objective is to provide context for non-economists seeking to understand the literature reviewed below. This review is not meant to be a guide to applying the models, or a judgment of which models are most appropriate for the economic analysis of predator control.

Cost-benefit analysis (CBA) is often used to assess the efficiency of alternative programs or policies. CBA asks the following question: Do the gains to society exceed the costs required? If the answer is yes, then the policy or program would make society better off. In this fashion CBA can be used to compare competing projects; compute the costs and benefits for each project, then select the project whose benefits exceed it costs by the greatest margin.

The description above implies that CBA should be applied on a societal scale. That is, all of the costs and benefits to all affected individuals in society should be considered. While this is true in theory it often difficult to uphold in practice. More often CBA is applied to a specific project with a narrowly defined scale. Cost benefit analyses of federal predator control programs in specific states are a case in point. In these cases the costs and benefits are generally restricted to a small subset of society, such as the costs borne by the federal agency and the benefits accruing to the state's livestock producers. When CBA is applied in this manner, the relevant question becomes: Do the gains of agricultural producers exceed the costs borne by the agency? If the answer is yes, then the federal expenditures may be deemed attractive from the perspective of the federal agency and livestock producers. This does not imply, however, that the control program is efficient on a broader scale. Specifically, there may be costs borne by individuals not considered in the analysis that would deem the program inefficient and thus unattractive. Readers of CBAs should therefore be cognizant of the scale of analysis implied because the scale can greatly impact the utility of the analysis for informing policy debates.

There are also several other issues with CBA in addition to the scale chosen. The most contentious issue relates to the valuation of non-market goods. Non-market goods refer to goods and services not sold in a market, such as wildlife viewing. Because they are not sold in a market, these goods generally lack an observable price. This makes valuing the benefits and costs of non-market goods particularly challenging. As a result, many CBAs are forced to exclude these goods which potentially bias the results. CBAs are also inherently anthropocentric (focus on costs and benefits to humans only) which some have argued biases CBA results in favor of natural resource depletion and environmental degradation. Finally, there are many issues that complicate CBA, such as: discounting (should benefits and costs that accrue in the future have less value than those that accrue today?), uncertainty (how should uncertain costs and benefits be accounted for?) and ecosystem complexity (how can we accurately predict the benefits and costs associated with complex ecological processes).

Despite the aforementioned challenges and common criticism, CBA can illuminate many research and policy questions about predator control. Properly conducted CBAs are highly transparent, with the measured (and often unmeasured) cost and benefits clearly indicated. This allows policy discussions to at least begin with a solid foundation and often helps focus debates. CBA also has the advantage of comparability. Alternative projects analyzed in different CBA's can generally be compared if the scale of the analyses is similar. This can reduce the time and cost of analyzing alternative programs. Finally, because CBAs attempt to value all benefits and costs, to all affected individuals, programs under investigation must be examined from all possible angles. The process of identifying all costs and benefits, and who is affected, is often the most illuminating step of a CBA.

Cost-effectiveness analysis (CEA) can be used to determine the least cost (i.e. "efficient") means to achieve a given objective. CEA differs from CBA because outputs, or benefits, are usually measured in physical rather than monetary terms. CEA could be used, for example, to determine the least cost combination of predator control activities (e.g. traps and shooting) to reduce predation rates by some fixed amount. CEA thereby alleviates the challenge of computing monetary benefits, which is often complicated by the presence of non-market goods. Cost-effectiveness of a specific project, however, does not imply that the project is efficient on a societal scale. An alternative project may generate greater benefits for the same cost. CEA is not generally amendable to the comparison of competing projects at broad scales; a CBA comparison of alternative projects would be more appropriate for such comparisons.

CEAs suffer from many of the same issues that plague CBA, including discounting, uncertainty and complexity (programs and their associated costs are often as complex as ecological processes). Additionally, the precision of a CEA is dependent on the definition of output because this definition determines the alternatives that can be included in the analysis. The more broad the definition of output (e.g. ungulates saved from predators vs. rate of predation on lambs), the greater the number of relevant alternatives (e.g. habitat improvements to antelope calving grounds may not be a relevant alternative if the output is the rate of predation on lambs). Furthermore, a CEA that excludes relevant alternatives may not identify the true cost-effective set of alternatives because any alternative not considered has the potential to be more effective than the included alternatives. Readers of CEAs should carefully consider the definition of output and the implication of that definition on the interpretation of the research results.

Despite the challenges mentioned above CEAs have several distinct advantages. First, CEAs are often easier (less costly and time consuming) to conduct because they avoid valuing program benefits and because data on costs are often more readily available. Second, CEA's are generally less controversial for exactly the reasons stated. Many people will be quick to debate the non-market value of a wolf, but given an objective for wolf populations few people will argue that the objective should be achieved at anything but least cost. Lastly, CEAs have the same transparency benefits of CBAs.

Cost-utility analysis (CUA) can be used to make comparisons between a range of competing alternatives. CUA measures the output of a program with utility, where utility measures the individual worth of a change following program implementation. This method was pioneered to evaluate health-care programs, where output is measured with quality adjusted life years. A similar approach could be used to evaluate predator control programs by measuring output in terms of the status of targeted species (e.g. livestock-production protection-years that measure the animal live weight protected over time with the program). CUA is most applicable to programs with goals that are achieved to varying degrees (e.g. predator control programs rarely protect all livestock or different types of livestock to the same degree), with outcomes that are not readily measured in monetary units and with outcomes that have inter-temporal effects (e.g. predators controlled in one year may protect livestock in subsequent years).

A challenge of applying CUA is the need to measure the final outputs of the program (i.e. cause and effect). For predator control programs, for example, a CUA may require data on the animal weights protected not just on the total predators removed. A major advantage of CUA is that it provides an explicit means to compare projects that have different objectives. Predator control programs, for example, could be directly compared to animal husbandry practices because the outputs from each could be measured in the same utility terms (e.g. additional animal live-weight per year).

The final economic method we review is budget analysis. Many different approaches exist in the literature that fit into the broad category of budget analysis. These approaches typically just report expenditure data with no clear framework for assessing the efficiency of the expenditures; budget analysis is therefore more accounting than economics. These approaches are useful because they provide baseline data on programmatic expenditures. Readers should use caution, however, when interpreting budget data because they often only include direct expenditures (e.g. actual cash outlays) and not indirect expenditures (e.g. opportunity cost of labor).

Annotated Bibliography

The following section provides a comprehensive list and short annotation of published documents that conduct, discuss or have relevance for economics analyses of predator control. We primarily focus on the recent literature (1986 – 2007), and separate journal articles from reports. Journal articles refer to any documents published in a peer reviewed academic journal; reports include all other documents, such as government reports and popular press sources that are not necessarily subject to the peer review process.

The bibliography begins with a table summarizing the distinguishing characteristics of this body of literature. The column headings in the summary table are defined as follows:

Case Study: indicates whether the study focuses on a specific, relatively small, location;
State or National: indicates whether the study focuses on the regional or national scale;
Theoretic-Model: indicates whether the study includes or is primarily a theoretical application that does not employ data;
Applied Model: indicates whether the study is an applied exercise that utilizes data;

Statistical Analysis: indicates whether the study uses statistical methods (e.g. regression analysis) to analyze data;
Exogenous Variable: indicates whether the analysis attempts to control for exogenous factors that may impact the effectiveness of predator control (e.g. weather);
Data Set: indicates whether the data set used in the study is included with the document;
Cost Estimate: indicates whether the study calculates the costs associated with predator control or predation;
Benefit Estimate: indicates whether the study calculates the benefits associated with predator control or predation;
Net Benefits: indicates whether the study calculates the net benefits or cost benefit ratio (i.e. cost-benefit analysis) associated with predator control or predation;
Wildlife: indicates whether the study includes predation of wildlife;
Livestock: indicates whether the study includes predation of livestock.

Article	Case Study	State or National	Theoretic Model	Applied Model	Statistical Analysis	Exogenous Variable	Data Set	*Cost Estimate	*Benefit Estimate	Net Benefit (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
Engeman, Shwiff, Smith, & Constantin								X			X	X

Article	Case Study	State or National	Theoretic Model	Applied Model	Statistical Analysis	Exogenous Variable	Data Set	*Cost Estimates	*Benefit Estimates	Net Benefits (BCA)	Wildlife	Livestock
2004 Continued												
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
1998												
Conner, Jaeger, Weller, & McCullough	X			X	X				X			X

Article	Case Study	State or National	Theoretic Model	Applied Model	Statistical Analysis	Exogenous Variable	Data Set	*Cost Estimates	*Benefit Estimates	Net Benefits (BCA)	Wildlife	Livestock
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

* Costs and benefits are given for predator control. Costs should not be confused with the costs predators inflict. Estimates of how many depredated animals there were and their associated values are listed as benefits of predator control in this annotation.

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 Assessment 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 population 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 male 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 insight 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 of 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 bad 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 potent 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.

Norwegian sheep producers, using the number of predators from 1994 and sheep losses from 1988-1993, report 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, 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 (eg non target species saved as a result of predation management), and (3) intangible (eg 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 1000% 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.

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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Appendix A: Economics of Predator Control to Protect Agriculture: The Unanswered Questions

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Introduction

For centuries humans have attempted to control population of mammalian predators to protect livestock populations. The United States government officially entered the predator control arena in 1915, when Congress appropriated funds for the control of wolves and coyotes (GAO, 2001). Since that time federal and state agencies have invested significant public resources in efforts to control predators to protect agricultural interests and to compensate agricultural producers for incurred losses. In 2007, for example, USDA APHIS Wildlife Services invested over $39 million in programs to protect agriculture (USDA, 2008). Concurrently, growth in the environmental movement has raised concerns about the efficacy and morality of such resource use (Connolly, 2001, Hewitt, 2001). Recent controversy surrounding the removal of endangered species status for the gray wolf (*Canis lupus*), specifically the negative public opinion of state management plans that would manage wolves similarly to coyotes, is a case in point.

Although disagreements between those with differing views of predator control are unlikely to ever disappear, it may be time to cast the predator control debate in a new light. In the last decade there has been a growing recognition of the value of ecosystem services provided by private agricultural land. This is particularly true for wildlife habitat in the Rocky Mountain region (RM), where, despite large tracts of public land, wildlife depend on private lands for much of their habitat needs (Coupal, et al., 2004). Concurrently, rural and ex-urban development is placing increasing pressure on land historically shared between livestock and wildlife. As a result, profitable agricultural production may be the last line of defense protecting many valued ecosystems from being permanently altered by development.

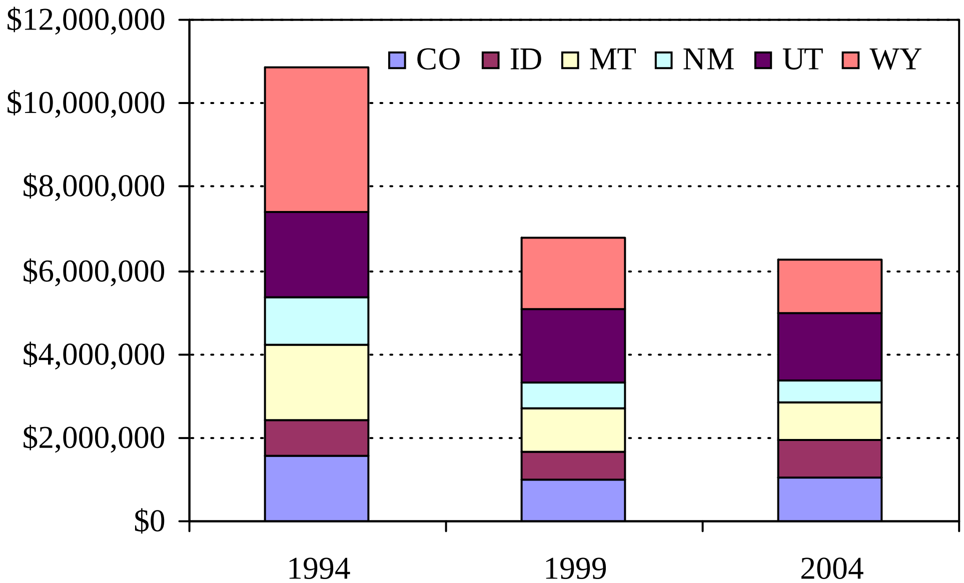
In this light, publicly subsidized predator control and compensation programs may be viewed as another tool to protect the provision ecosystem services from private land. In this context it is increasingly important that policy makers have accurate scientific information about the effectiveness of such programs for protecting the profitability of agriculture. The purpose of this article is to review existing research in the light of this new context and to provide direction to more targeted future research. We describe why predator control is still an important issue for agriculture in the West, and consider the role that economic research has and can play in assessing the role of predator control programs for protecting agricultural lands. We review the literature and argue that existing analyses of predator control generally lack detail about the bio-physical processes related to predator control and therefore cannot adequately assess the tradeoffs between predator control and alternative agricultural support programs. Lastly, we suggest a more comprehensive framework for future economic analyses.

Financial Impacts of Livestock Depredation in the West

Predation continues to have a measurable financial impact on many sectors of the agricultural economy. This is particularly true for the production of sheep and lambs, where the value of losses due to predators, primarily coyotes, exceeded $6 million in 1994, 1999 and 2004 (Figure 1). These losses account for 2 – 11% of the annual total value of sheep production in these western states. Furthermore, predation routinely accounts for greater than 50% of the annual death loss of lambs in the RM region (National Agricultural Statistics Service, 1995, 2005, 2000).

Direct financial impacts of predation, however, are not limited to sheep and lambs. Predation losses generally account for 1-2% of total cattle inventory in the region and greater than 5% of total calf inventory (USDA, 2000). Additionally, in areas with robust populations of large predators (wolf and grizzly bear) predation on cattle and calves can be significant. In the Upper Green River Cattle Allotment located in the Greater Yellowstone Region of northwest Wyoming, for example, confirmed predation by grizzly bears and wolves accounted for more than 50% of total death loss from 1995 to 2004 (Sommers, et al., 2008). An alternative study in the same region found that grizzly bears were responsible for 39% and 12% of total calf and adult cattle mortality, respectively (Anderson, et al., 2002).

Figure 1. Dollar value of sheep and lambs lost to predators by State, 1994, 1999 and 2004 [Source: National Agricultural Statistics Service (1995, 2005, 2000)]



Dollar figures are adjusted to real terms using the GDP deflator, base year 2004.

While the financial impacts of predation on livestock production are measurable, they remain small relative to the total value of production. As a result some have argued that federally subsidized predator control programs are unnecessary (e.g. Berger, 2006). Livestock operations in the west, however, routinely maintain slim to negative profit margins (Jones, 2004). Furthermore, the negative financial impacts of predation are not evenly distributed across the landscape. Thus, while the livestock industry in a given region may experience relatively small aggregate losses, those losses may primarily impact a few producers that operate in areas most prone predation. If areas prone to high predation rates also coincide with agricultural land that is highly susceptible to land conversion (e.g. agricultural land in the Greater Yellowstone Region), the financial impacts of predation may be an important factor threatening agricultural profitability.

Thus, even small depredation losses that reduce annual gross margins can threaten the economic sustainability of agricultural production and the associated ecosystem service provided from agricultural lands.

Lastly, in addition to the direct effects of predation, the financial impacts of predation also ripple through the broader regional economy due to employment and income linkages across economic sectors. Jones (2004), for example, estimated that predation in the RM region in 1999 caused approximately $7 million in direct losses to the livestock industry. These direct losses led to an additional $5.6 million dollars of indirect losses in allied sectors.

Economics of Predator Control to Protect Agricultural Lands: State of the Literature

Economic theory suggests that the conversion of agricultural land to development will occur if the present value of the stream of net returns from agriculture is less than the net returns from development (Irwin, et al., 2003). Thus, policy-makers must understand how predator control programs contribute to the long term net returns of agricultural production to assess the effect of these programs on land protection. This implies the need to understand 1) the biological relationship between relevant predators and their prey, including livestock, 2) how predator control efforts affect predator-prey relationships and thus the effect of predator control on livestock production, 3) cost-effectiveness of alternative control methods, and 4) the economic efficiency of predator control relative to alternative agricultural support programs.

The literature contains numerous economic analyses related to predator control efforts. Surprisingly few, however, directly model the biological predator-prey relationships such that the effects of explicit control efforts on livestock production can be derived. Several studies have explicitly modeled predator-prey relationships with respect to wildlife species of concern (Rashford and Adams, 2007, Shwiff, et al., 2005, Skonhoft, 2006). These studies use available data to parameterize or statistically estimate functional relationships between either predator and prey populations, or alternatively, predator populations and levels of predator control effort. Thus they develop functional representations of the biological predator-prey relationships, which can then be explicitly integrated into an economic optimization problem.

With respect to livestock depredation, few studies have developed similar bio-physical predator-prey relationships. Data on the interactions between predators and livestock and livestock losses relative to specific control efforts have been collected in biological experiments (e.g. Anderson, et al., 2002, Wagner and Conover, 1999). Alternatively, regression techniques have been used to examine correlations between predator populations or control efforts and livestock outputs (Berger, 2006, Conner, et al., 1998). These studies, however, do not attempt to develop functional relationships. Moreover, studies of this nature tend to (often by necessity): 1) focus on a single pair of predator and prey species, 2) have limited temporal and spatial extent, and 3) focus on one of a large suite of predator control alternatives applied at a single (or a few) level(s) of intensity. As a result, these studies do not reveal the range of substitution possibilities among the set of controllable (e.g. predator control efforts) and uncontrollable (e.g. weather and alternative prey populations) inputs, and the associated response of livestock populations (see Matulich and Adams, 1987, for an in-depth discussion of this problem). An exception to this criticism can be found in the bio-economic analysis of feral pig predation on lambs in Australia by Choquenot and Hone (2000). This analysis uses dynamic models of predator populations and lamb predation to simulate the economic impacts of multiple control options in a bio-economic model that incorporates exogenous factors (e.g. rainfall) and inter-specific competition.

The general lack of explicit bio-physical models of predator-prey relationships in the context of livestock production has forced studies of the economic efficiency of predator control to use aggregate data approaches. Several studies, for example, have used a benefit-cost approach to examine the efficiency of programmatic expenditures on predator control (Bodenchuck, et al., 2000, Collinge and Maycock, 1997, Shwiff and Merrell, 2004, Shwiff, et al., 2006). These papers account, as accurately as possible, for aggregate benefits and costs, including indirect benefits (e.g. spillovers to other economic sectors) and indirect costs (e.g. non-programmatic costs born by individual producers). However, because of the aggregate nature of the data used, there is no direct relationship between alternative control efforts and agricultural profitability. The benefits of predator control, for example, are often measured by damages avoided assuming a linear relationship between control efforts and predation rates (e.g. predation rates are 1-3% higher in the absence of control efforts).

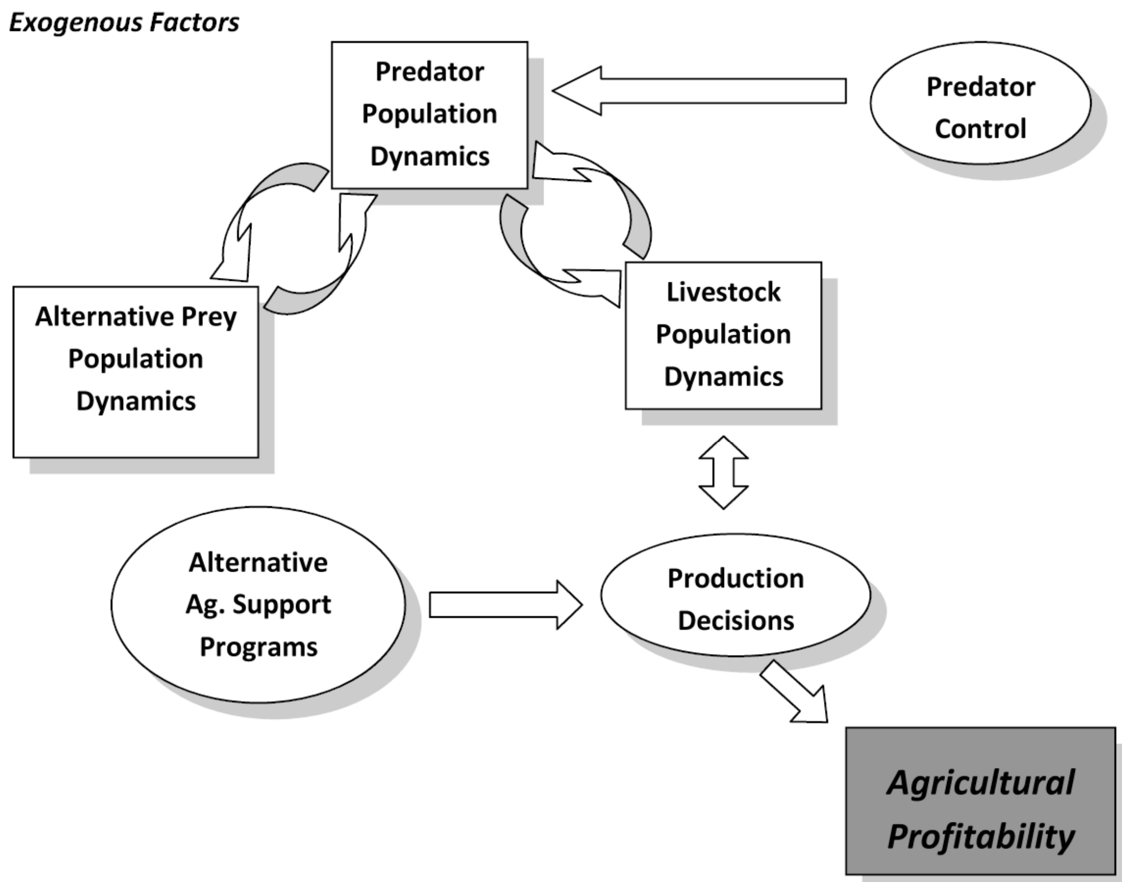
Therefore, the aggregate benefit-cost approach is most useful for determining the aggregate net benefits of control expenditures and therefore justifying the existence of control program in general. However, this approach does not illicit the biological or economic tradeoffs between alternative control strategies and therefore cannot determine the cost-effectiveness of alternative control methods. Furthermore, because these approaches do not directly link predator control efforts to agricultural profitability, it would be difficult to use this approach to compare predator control programs to alternative agricultural support programs as a means of preserving agricultural land.

Looking to the Future

As evidenced by the literature, we lack a firm understanding of the complex relationship between predator control programs and firm-level agricultural profitability. As a result, their currently exists no framework for analyzing the role that predator control programs can play in the broader effort to preserve agricultural land. Such a framework must explicitly model the population dynamics of predators and prey and these dynamics must be explicitly linked to agricultural production decisions (Figure 2). In this fashion the effects of predator control efforts and alternative agricultural support programs can be analyzed on the basis of how they impact agricultural profitability.

The development of a framework that incorporates all of the components of figure 2 will require significant interdisciplinary cooperation. Biologists will need to collect data and build models of population dynamics, and conduct experiments on the bio-physical effects of alternative predator control efforts. Animal scientists will need to build models of livestock population dynamics. Finally, economists must integrate these components into agricultural decision-making models. Factors key to the success of such a collaborative effort include: 1) the constituent models must be capable of capturing the effects of the full range of predator control and agricultural production inputs so that substitution possibilities and complementarities across inputs can be examined, 2) the effects of exogenous factors (e.g. weather) must be accounted for so that uncertainty can be explicitly modeled and so that the robustness of model conclusion can be tested under alternative scenarios, such as climate change, and 3) the constituent models must be developed in concert across disciplines so that they can be seamlessly integrated.

Figure 2. Conceptual framework for understanding the relationship between predator control efforts and agricultural profitability.



The development of this framework will require significant cross-disciplinary research effort. The result, however, will be a model capable of eliciting the economic tradeoffs between alternative predator control activities at multiple scales and between predator control and alternative agricultural support programs. This will allow policy-makers to make informed decisions about the use of scarce resources and will allow the predator control debate to be analyzed in a new light.

Conclusions

Debates over the economic efficiency, biological efficacy and morality of predator control programs to protect agriculture are unlikely to be resolved in the near future. These programs, however, may be an important piece of comprehensive agricultural support programs that protect the sustainability of agricultural production and the associated ecosystem service that agricultural lands provide society. This view of predator control is fundamentally different than the perspectives represented in existing economic analyses of predator control. As a result, the evaluation of predator control programs as a component of agricultural land protection programs will require a new, more comprehensive and interdisciplinary, approach to predator control research. This new approach must explicitly integrate the population dynamics of predator and prey systems within an agricultural decision-making framework. In the absence of such research policy-makers will be unable to fully evaluate the efficiency of predator control programs relative to alternative agricultural support programs.

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Evaluating the potential influence of predation on Jackson moose
Final Report to the Wyoming Animal Damage Management Board

Submitted by: Dr. Matthew Kauffman, Assistant Leader for Wildlife and Janess Vartanian, MS Student, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming.

Project Description

Shiras moose (*Alces alces shirasi*) in the Jackson Herd Unit, have been experiencing a population decline for the last 11-16 years (Brimeyer and Thomas 2004). Recent research has shown that these animals are highly migratory and that some moose wintering in the Buffalo Valley migrate north to spend summer in southern portions of Yellowstone National Park (YNP) and the Absaroka Herd Unit (Becker 2008). Seasonal habitats, home range characteristics, and physiological health of adult female moose in the Jackson herd unit were characterized by Becker (2008). By evaluating the condition and demography of captured moose, this earlier work suggested that habitat quality and its effects on the physical condition, survival, and reproductive success of cow moose appears to be the primary factor limiting population growth. However, the potential effects that predation may have on this population remain unknown. Grizzly bears and wolves have been responsible for some mortalities of collared moose. This study has followed up on many of the initial objectives of Becker's research and evaluated more closely the influence of habitat condition and nutritional quality of forage on moose reproduction and survival. As a separate component, ADMB funding was sought to continue work evaluating the potential influence of predation on moose.

Objectives of the Jackson moose project supported by ADMB funding include:

1) to monitor parturition rates, neonate and calf survival
2) to evaluate different non-invasive field approaches for the estimation of bear presence/absence (i.e., hair-snares, and remote camera trapping)
3) to collect both bear and wolf scat for diet and genetic analysis

Project Results 2008

Winter 2008 produced record snow falls within the study area, which postponed moose migration to summer range until July and likely resulted in increased stress and poor condition of adult female moose. A stressful winter in 2008 was evidenced by low pregnancy (75% vs 91%), decreased adult female survival (Fig. 1), low parturition (Fig. 2) and a high number of mortalities observed in winter and spring compared to previous years. During the June parturition survey, 11 adult female moose were seen with a calf at side. In July, 6 of 11 adult female moose still had a calf at side during the neonate survival flight. Thus, neonate survival (Fig. 3) was comparable to Becker's earlier work. Upon return to winter range, calf surveys revealed that 33% of calves had survived and returned to winter range (Fig. 3).

During 2008, 23 radio-collared individuals (20 cows, 3 bulls) were lost from the study. Upon detecting a mortality signal, field necropsies were conducted as soon as possible to determine cause of death. Of these, 19 were confirmed mortalities, 3 were dropped collars and 1 was not investigated. To assess condition at time of death, 11 bone marrow samples were collected from deceased moose. Upon drying, 9 of 10 useable samples suggested that moose were in poor to starvation condition (Fig. 4) at time of death (one bone was devoid of any marrow for analysis).

Since moose exhibited late migration, data from phase one was used to determine the sampling location for testing hair snares and remote camera trapping to assess bear use. Mink Creek had the highest proportion of adult female moose that lost neonates in phase I, and was thus selected as the sampling area. In July, 6 hair snares and 5 cameras (Fig. 5) were placed in the Mink Creek sampling area and maintained every 4-7 days for the duration of the month. The hair snares successfully snared one hair sample, which the associated camera revealed as porcupine. The cameras were set up facing the hair snares to test the effectiveness of each method in detecting bears. The cameras were successful in detecting, one porcupine, multiple ungulates, and one black bear (Fig. 6), although hair was not snared at the associated snare.

Both bear and wolf scat were collected across the study area when located. We collected 29 wolf scats and 80 bear scats (Fig. 7), 23 of which were associated with grizzly tracks. Adult bear scats (n=75) were sent to Big Sky Beetle Works (Montana) for diet analysis and Wildlife Genetics International (British Columbia) for species identification (Figs. 9 &10; Table 1). Of the bear scats collected, 67 were grizzly bear, 5 were black bear, and 3 were unable to be identified. Only grizzly scats contained animal residues, while all scats contained vegetation. Animal species identified in diets included: moose, elk, white-tailed deer, black bear, grizzly bear, wolf, unknown waterfowl, unknown rodent, ants, and unknown bone fragments. Grizzly bear scats were detected in all moose summer ranges, while black bears were only detected in 3 summer ranges.

Project Results 2009

Winter 2009 was more normal when compared to those observed during Becker's research. Pregnancy rates rebounded to 80%, however, this was calculated from a small sample size (n=5) and is still below the average obtained during Becker's study (91%). Adult female survival rebounded to 80% from 63% observed following winter 2008 (Fig. 1). Parturition rates of captured moose remained consistent with previous years, while that of non-handled moose rebounded to 72% (Fig. 2). During the June parturition survey 19 of 31 adult female moose were seen with a calf at side. In July, 7 of 19 adult female moose still had a calf at side during the neonate survival flight and 2 late births were documented. Thus, neonate survival (Fig. 3) was the lowest observed over the duration of the Jackson moose study. Calf survival will be assessed upon return of adult female moose to winter range.

During 2009, 10 radio-collared individuals (8 cows, 2 bulls) were lost from the study. Upon detecting a mortality signal, field necropsies were conducted as soon as possible to determine cause of death. Of these, 9 were confirmed mortalities and 1 was a dropped collar. To assess condition at time of death, 6 bone marrow samples were collected from deceased moose, one of which was a calf. Upon drying, samples suggested that moose were in moderate condition (Fig. 4) at time of death.

Project Summary

Many Jackson moose vital rates are below average when compared to other moose populations that also exist amidst viable predator populations. These rates include, average adult ($\geq$ 2 yr) female survival (80% vs 88%), average adult pregnancy (80% vs 92%), average parturition (71% vs 87%), and average calf survival (42% vs 56%), for Jackson moose compared to an average from the literature, respectively. The harsh winter of 2008, negatively influenced all survival rates, even adult female survival, which is generally a very stable rate in ungulate populations. In addition, the stress of winter 2008 appeared to carry over to influence neonate survival the following year. Such patterns suggest that summer range may not be in good enough condition for adult female moose to fully replace fat losses incurred during winter, and supports the notion that poor habitat continues to constrain the recovery of the Jackson moose population. Some collared adult female moose have been lost due to predation. However, only 11 of 75 bear scats collected during summer 2008 contained animal hair or bone, and only 2 contained moose hair. Thus, although we have evidence of grizzly bear consumption of moose, predation does not appear currently to be a major source of moose mortality.

FIGURE 1. Survival of adult female moose across both phases of the Jackson moose study project.

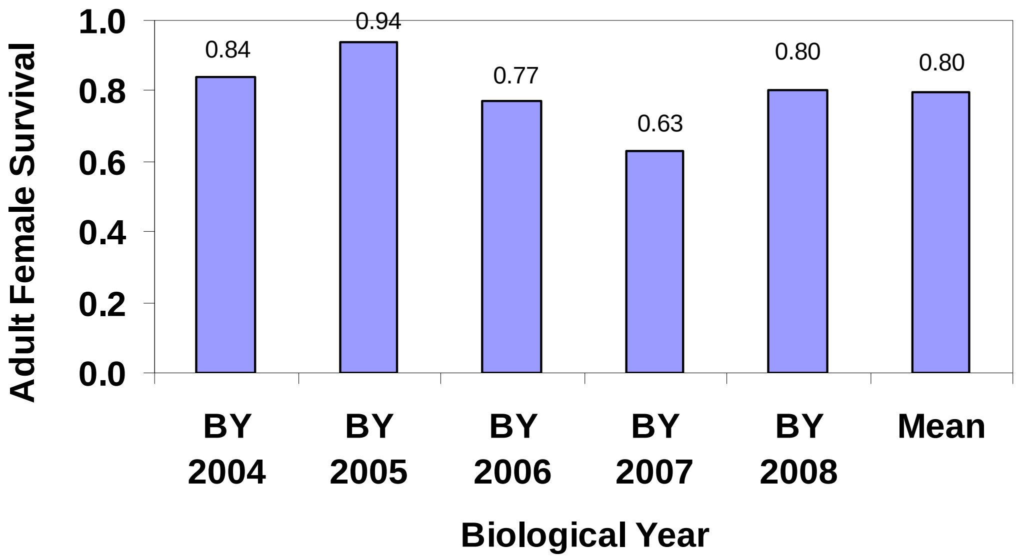

FIGURE 2. Parturition of non-handled (blue) and handled (purple) moose across both phases of the Jackson Moose Project. *Note, BY 2009 captured parturition sample size is low (n=5).*

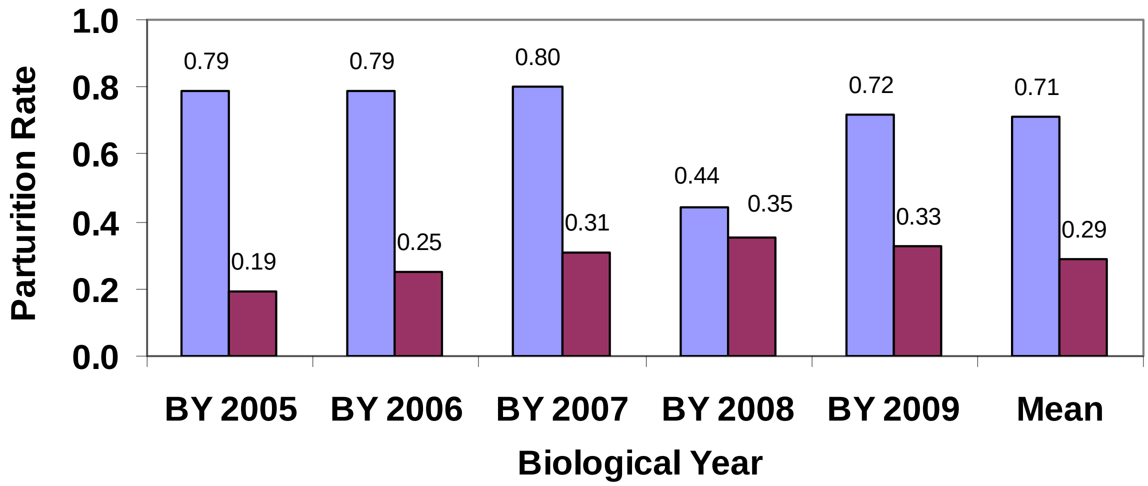

FIGURE 3. Neonate and calf survival for both phases of the Jackson moose project.

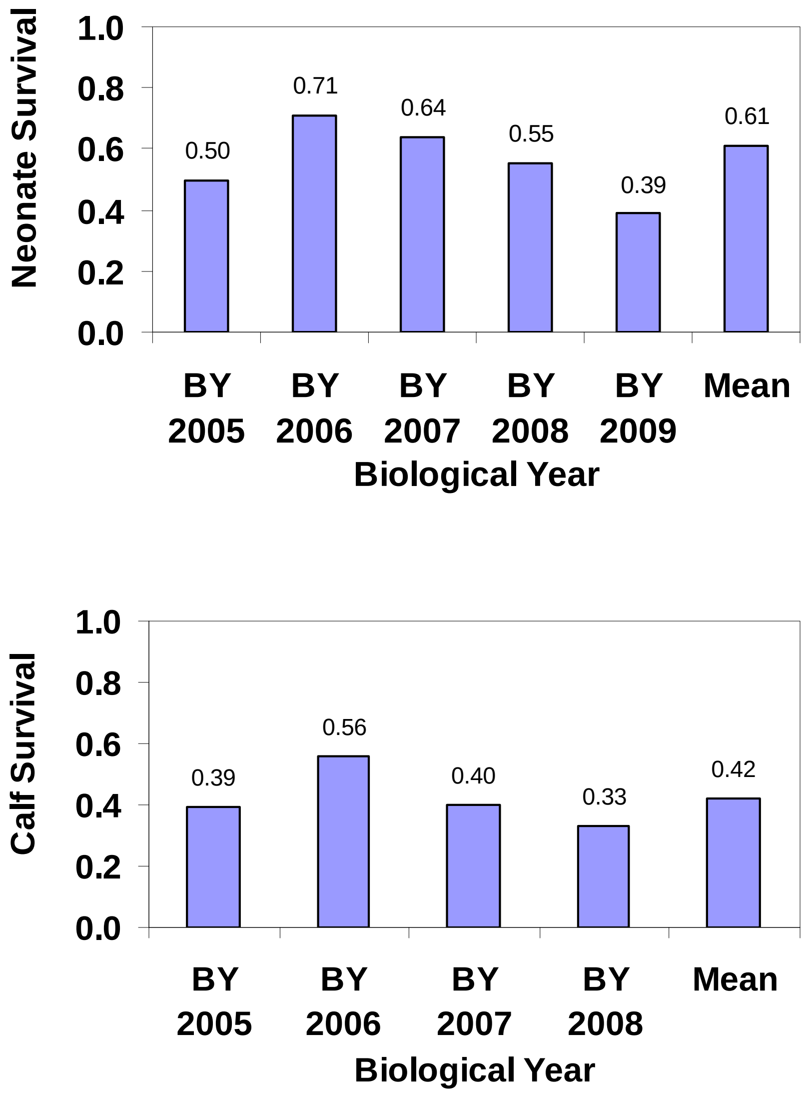

FIGURE 4. Percent bone marrow fat of dead moose, winter 2008 and 2009. Overall, most moose were in a compromised condition at time of death.

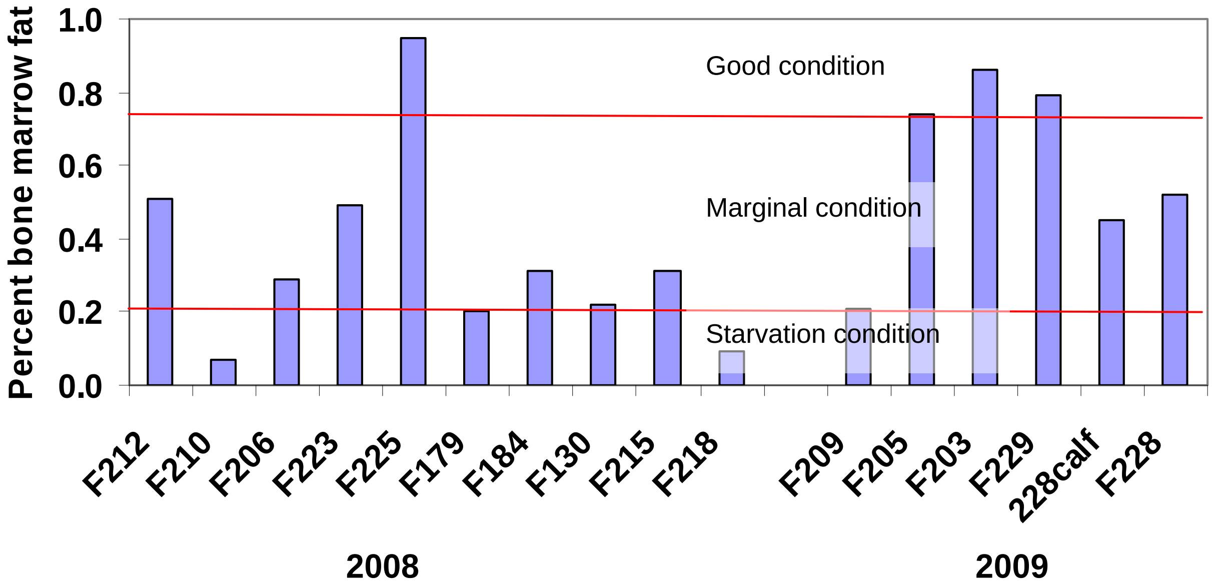

FIGURE 5. Location of hair snares and remote camera stations (yellow squares) within Mink Creek sampling area (red polygon).

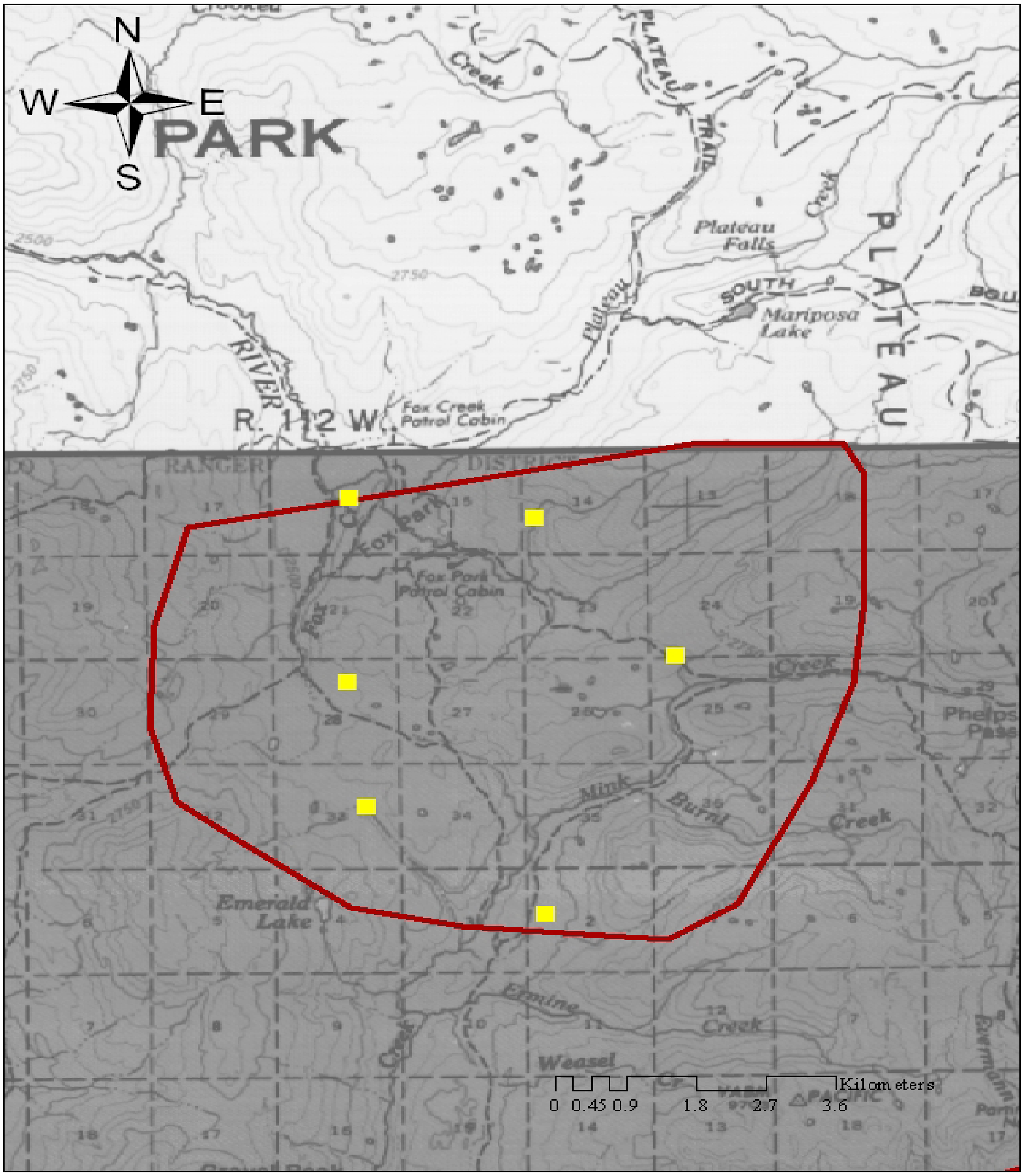

FIGURE 6. Images of hair snare visits, summer 2008. Cameras recorded images of a porcupine (top), a black bear (center) and deer (bottom).

FIGURE 7. Locations of carnivore scats collected during summer 2008.

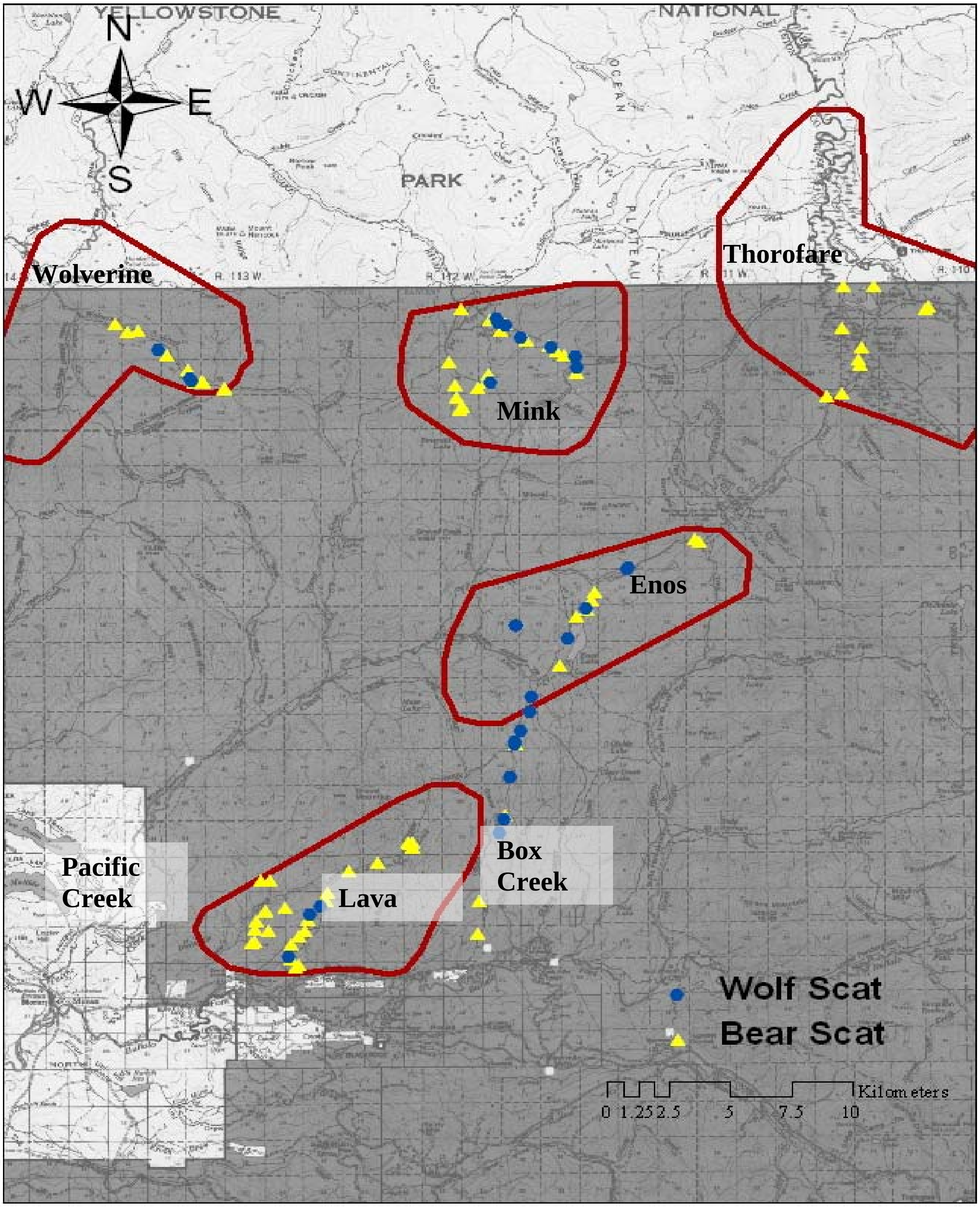

FIGURE 8. Locations of moose neonates that survived (plus sign) and did not survive (circles) the first 6 weeks of life (late May – mid July) during 2008 and 2009.

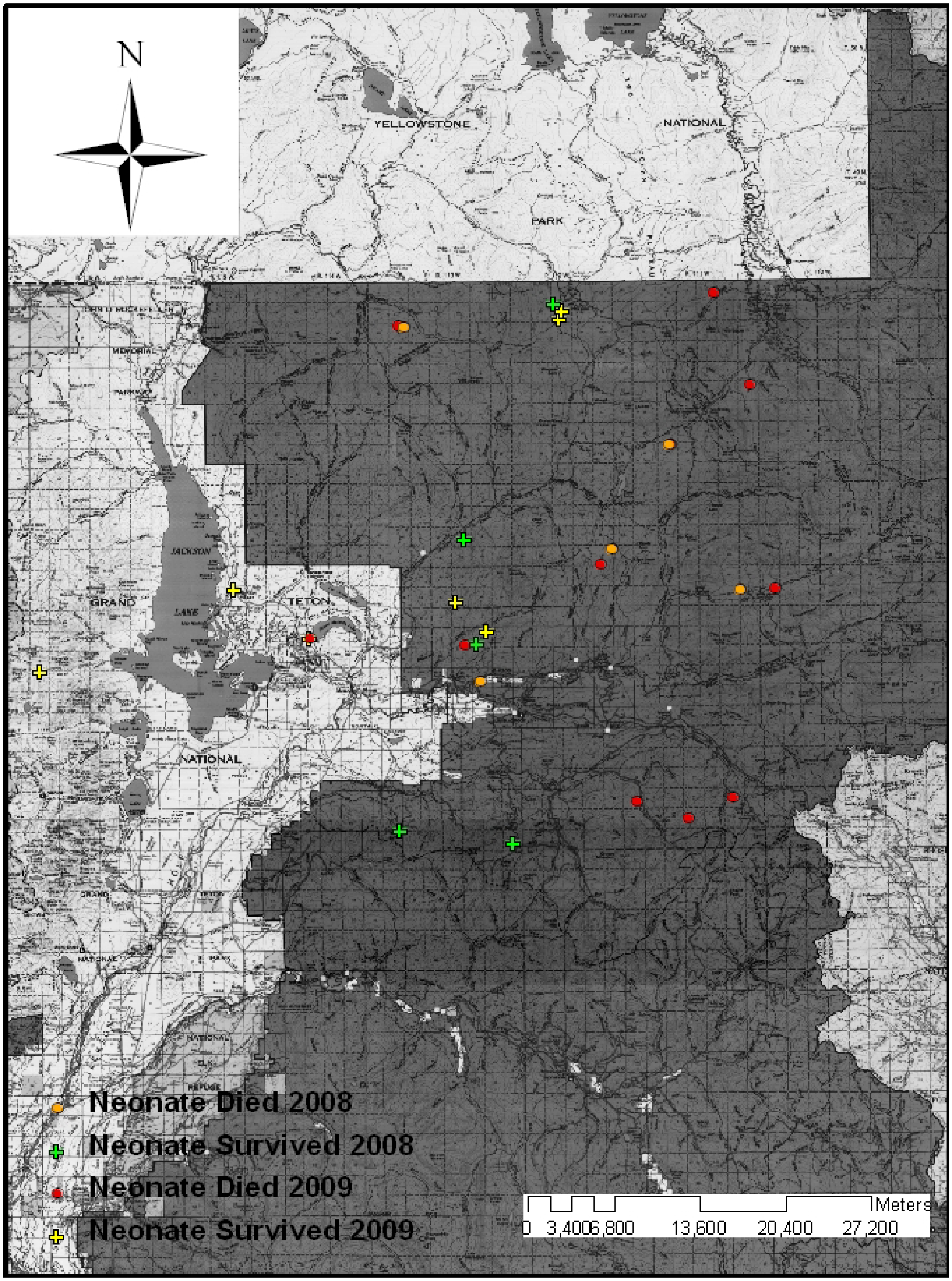

FIGURE 9. Grizzly and black bear scats identified in each summer sampling area (Enos, Lava, Mink, Thorofare and Wolverine) and other areas within potential summer moose habitat (Box Creek, Pacific Creek). Areas are represented as: Enos (E), Lava (L). Mink (M), Thorofare (T), Wolverine (W), Box Creek (BC), and Pacific Creek (PC).

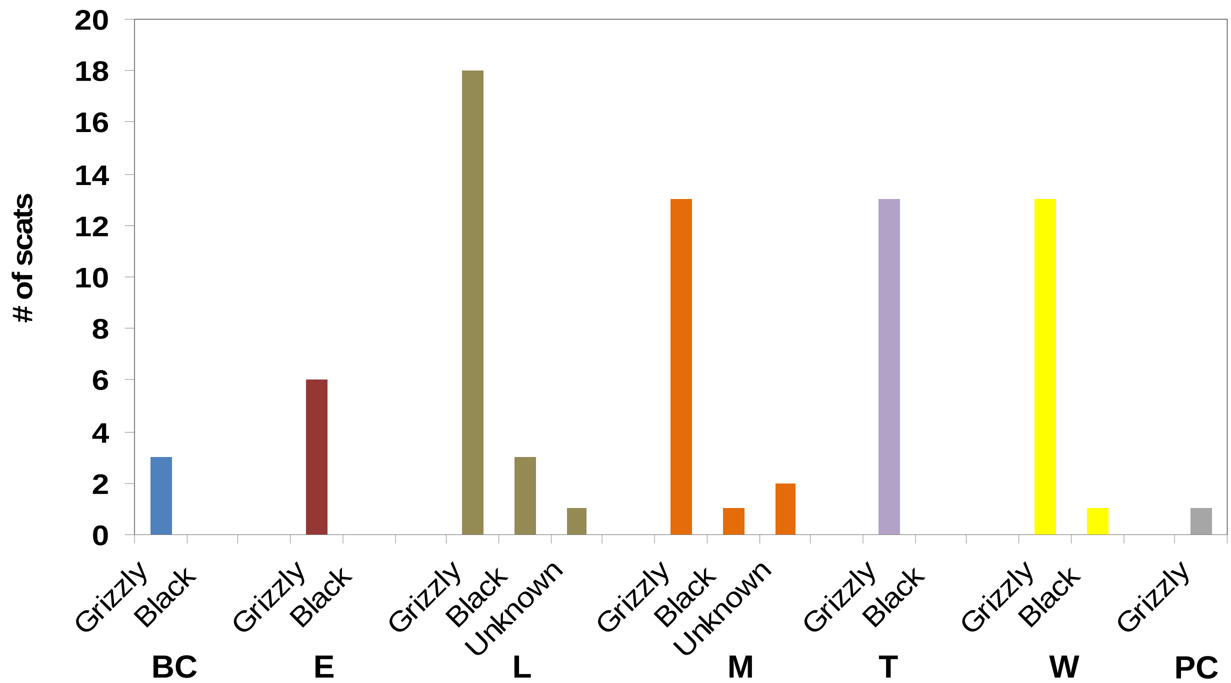

FIGURE 10. Animal and plant content of bear diets determined from microhistological analysis of bear fecal samples.

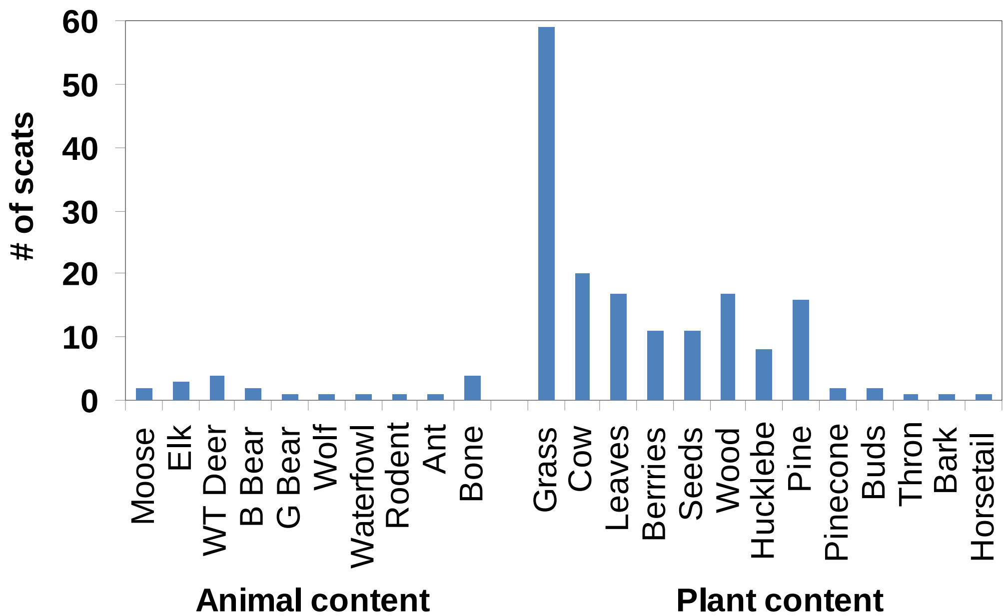

TABLE 1. Bear scat content within each collection area. Number represents, the number of scats in each area that contained each foraging component. *Note: Pacific Creek scat (n=1) not represented, it contained 100% vegetation, mostly cow parsnip.*

	Box Creek	Enos	Lava	Mink	Thorofare	Wolverine
Animal						
Moose - hair	-	-	1	-	1	-
Elk - hair	-	-	1	1	1	-
White tail deer - hair	-	1	1	1	1	-
Black bear - hair	-	-	-	1	1	-
Grizzly bear - hair	-	-	1	-	-	-
Wolf -hair	-	-	1	-	-	-
Waterfowl - feather/shell	-	-	-	-	1	-
Rodent - unk spp.	-	1	-	-	-	-
Ants	-	-	1	-	-	-
Bone fragments - unk spp.	-	2	1	1	-	-
Vegetation						
Grass	-	6	17	15	8	13
Cow Parsnip	3	1	8	1	6	1
Leaves	-	4	4	2	2	5
Berrries	-	4	4	1	1	1
Seeds	-	1	4	1	2	3
Wood	-	3	6	3	2	3
Huckleberry - plant	-	1	5	-	1	1
Pine needle	1	-	7	4	2	2
Pinecone	-	-	1	-	-	1
Buds	-	-	2	-	-	-
Thron	-	-	1	-	-	-
Bark	-	-	-	-	-	1
Horsetail	-	-	-	-	1	-

ADMB PROJECT REPORT

Project Title: North Fork Human-Bear Conflict Resolution

Brief Synopsis of Project: This project will minimize human-bear conflicts in the North and South Fork of the Shoshone River area through (1) minimizing and properly managing bear attractants; (2) employing bear resistant waste management systems; (3) managing bears/attractive bear habitat where potentials for conflicts and risks to human safety are high; and (4) employing a public outreach program for education about preventing conflicts with bears.

FY09 Expenditures: The ADMB awarded $10,000 in FY09 to be directed toward educational initiatives for the purpose of minimizing human-bear conflicts in western and central Park County. A total of $6,415.12 has been utilized for the purchase of the following: 1) 7000 "Be Bear Aware" children's coloring books, 2) 140 inert bear spray training canisters, 3) A "Be Bear Aware" highway billboard posted on the North Fork highway in Wapiti, Wyoming, 4) 300 "Be Bear Aware" refrigerator magnets used in an informational mailing to North Fork residents, 5) Technical equipment for the "Be Bear Aware" public library display including a hard drive, 22" touch screen monitor, and headphones, 7) Preservation of a grizzly bear skull as well as front and back paws for use in the public library display and 6) Fall 2008 Hunting in Bear Country, 2009 Black Bear, Grizzly Bear ID, and 2008/2009 Living in Bear Country public service announcements that ran seasonally on 3 radio stations in 2-3 week increments.

Submitted by: Tara Teaschner, Bear Wise Community Coordinator
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October 13, 2009

Kent Drake
Predator Management Coordinator
2219 Carey Ave
Cheyenne, WY 82002

Dear Kent:

Please consider this letter as the FY09 final report for the Wildlife Services/Wyoming Game and Fish Department Contract dealing with trophy game animal damage investigation and mitigation. This project has been one of the longest running projects continually supported by the Animal Damage Management Board (ADMB). The scope of the project has varied over the years, but the basic concept, providing a high level of timely and professional damage evaluation service to livestock producers and ensuring human health and safety have always been the core concepts of this project. It is apparent that Department personnel working in concert with Wildlife Services personnel can respond to the needs of the public, especially the livestock industry, in a more effective manner if both parties worked together. The project has proven valuable in the investigation and mitigation of damage efforts and for compensation actions for claimants.

In FY09 the ADMB allocated $25,000.00 for this project. A total of $12,908 was billed consisting of 308.6 hours of specialist time and 8.4 hours of flight time. During this same time, Department personnel investigated 78 claims for damage to livestock by trophy game animals (black bear, grizzly bear, mountain lion and wolves in that portion of the state where wolves are classified as trophy game animals) in the amount of $287,325.33. Department personnel drove 240,433 miles and expended 24,702 man hours responding to nuisance animal calls and damage situations at a cost of $1,070,700. Clearly assistance from Wildlife Services personnel provides significant support to this effort.

I would like to thank the ADMB for their continued support of this project and will provide any additional informational needs relating to this project upon request.

Sincerely,

Scott Talbott
Assistant Chief, Wildlife Division

ST/st
Cc: L. Lembeck,
J. Doering.