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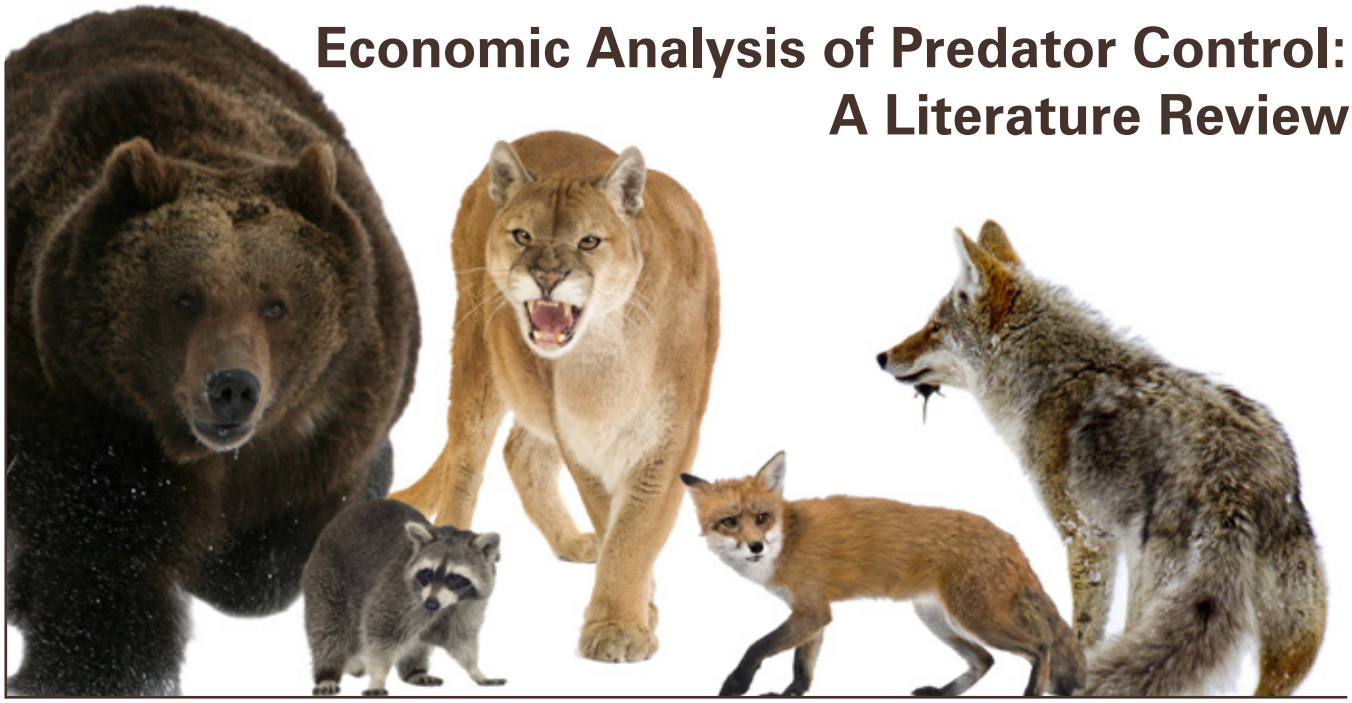
Economic Analysis of Predator Control: A Literature Review



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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 the applicability of economics 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 service 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 understanding the economics of predator control.

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

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

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 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 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. Keeping the concept of efficiency in mind is important when reviewing economic literature because each author's specific notion of efficiency typically drives the research questions asked and the research design.

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. 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. The objective is to provide context to understand the literature reviewed below and to stimulate future research.

Cost-Benefit Analysis

Cost-benefit analysis (CBA) is often used to assess 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 its costs by the greatest margin. CBA is the most common approach in existing literature. The purpose of most of the surveyed CBA articles is to demonstrate that federal predator control programs yield positive net benefits.

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 true in theory, it is often difficult to uphold in practice. More often, CBA is applied to a specific project with a narrowly defined scale (e.g., federal programs at the state level). 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. There may be costs borne by individuals not considered in the analysis that would deem the program inefficient and thus unattractive (e.g., the sightseeing values of wildlife enthusiasts). Readers of CBAs should be cognizant of the scale of analysis implied because the scale can greatly affect the utility of the analysis for informing policy debates.

There are 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 exclude these goods or attach an arbitrary multiplier to the calculated benefits and costs, both of 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 including 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 criticisms, 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 CBAs can generally be compared if the scale of the analyses are 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

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 then 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 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 because any alternative not considered has the potential to be more effective than those included. 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, CEA has 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, CEAs are generally less controversial for exactly the reasons stated above. Many 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

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 healthcare 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 example, a CUA for a predator control program may require data on the animal weights protected in addition to 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 units (e.g., additional animal live-weight per year).

Budget Analysis

The final economic method we review is budget analysis. Many different approaches exist 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; as a result, budget analysis requires more accounting than economics. These approaches are useful because they provide baseline data on programmatic expenditures. Readers should use caution 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, economic 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 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;

Theoretical 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 uses 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	Theoretical model	Applied model	Statistical analysis	Exogenous variable	Data set	*Cost estimate	*Benefit estimate	Net benefit (CBA)	Wildlife	Livestock
2007												
Frey and Conover	X				X						X	
Schiess-Meier, Ramsauer, Gabanapelo, and 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, and Jaeger	X							X				X
Berger		X		X	X	X		X	X	X		X
Duffield, Neher, and Patterson	X				X		X		X	X	X	X
Shivik								X				X
Shwiff, Sterner, Kirkpatrick, and Engeman		X					X	X	X	X		X
Skonhoft		X	X	X			X	X	X	X	X	
2005												
Bright and Hervert	X			X		X	X	X			X	
Shwiff, Sterner, Turman, and Foster	X			X	X	X	X	X	X		X	
2004												
Allen and Fleming		X		X			X	X	X			X
Andelt							X	X				X
Asheim and Mysterud		X		X	X		X	X	X	X		X
Brek and Meier		X					X		X			X
Engeman, Shwiff, Smith, and Constantin								X			X	X

Article	Case study	State or national	Theoretical model	Applied model	Statistical analysis	Exogenous variable	Data set	*Cost estimates	*Benefit estimates	Net benefits (CBA)	Wildlife	Livestock
2004 Continued												
Fagerstone, Johnston, and Savarie								X				X
Jaeger								X				X
Jones		X		X			X		X			X
Shivik								X				X
Shwiff and Bodenchuk							X		X			X
Shwiff and Merrell	X						X	X	X	X		X
2003												
Engeman, Shwiff, Cano, and Constantin	X			X			X	X	X	X	X	
2002												
Anderson, Ternent, and Moody	X			X	X		X		X			X
Engeman, Shwiff, Constantin, Stahl, and Smith	X			X				X	X	X	X	
2000												
Bodenchuk, Mason, and Pitt		X		X			X	X	X	X	X	X
Yoder			X					X	X	X		X
1999												
Phillips and Martley		X								X		X
Wagner and Conover	X			X	X			X	X	X		X
1998												
Conner, Jaeger, Weller, and McCullough	X			X	X				X			X

Article	Case study	State or national	Theoretical model	Applied model	Statistical analysis	Exogenous variable	Data set	*Cost estimates	*Benefit estimates	Net benefits (CBA)	Wildlife	Livestock
1997												
Collinge and Maycock	X			X			X	X	X	X		X
1995												
Henke and Knowlton								X				X
1993												
Connolly		X						X				X
1986												
Smith, Neff, and 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 three-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 lions depredate more livestock in dryer times, likely due to a lack of alternative prey.

Reports

Wyoming Game and Fish Department. "An Assesment of Changes in Elk Calf Recruitment Relative to Wolf Reestablishment in Northwest Wyoming." Wildlife 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 percent of the change in sheep numbers from year to year. This model suggests 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 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 incite behavior modification. This publication provides examples of predator management and their associated economic and biological efficiency. Disruptive stimuli that were examined in this article include fladry (the use of flags to deter predators from entering an enclosed area), The Electronic Guard (a sensor that activates strobe lights and sirens at night), plastic protection collars, the ScareCall (programmable light and sound device), and radio activated guards (devices that activate when collared predators approach). The article notes 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: 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 percent 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. This report also states wolf predation has a moderate impact on elk and livestock populations. Final results indicate 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 the WS program provides more benefit to local economies than replacement programs could because of efficiency from economies of scale. The WS program is established and utilizes vast resources to mitigate wildlife damage. The report estimates total benefits from WS 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 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 (ungelded) 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 two 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-44s, 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-44s 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-44s and sodium cyanide poses no risk to the environment. The limited use of M-44s 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 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 are successful in selectively targeting 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 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. Nationwide 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 predator populations are large.

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

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

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

A cost-benefit analysis of coyote removal (aerial hunting and M-44s) in two areas of Carbon County, Wyoming, indicates 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, the authors determine several cost-benefit ratios, all of which considered coyote removal cost-effective.

2003

Journal Articles

Engeman, R. M., et al. "An Economic Assessment of the Potential for Predator Management 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). Monetary values for the parrot are established by examining captive breeding costs. The costs of predator management are determined and a benefit-cost analysis is performed. The results indicated the management is cost-effective if at least 1.4 parrots are saved per year.

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 bear 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 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 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 per 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 percent to 0.9 percent in treated pastures. This article indicates that aerial hunting had two benefits: a reduction in lamb losses to coyote predation and a reduction in the hours of summer pasture management.

Reports

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

The Wyoming Territorial legislature authorized a 50-cent bounty for wolves in 1875. Federally funded predator control began in Wyoming in 1915. Back then, the Wyoming-South Dakota District of the Biological Survey produced an estimated 1,000 percent return to government dollars spent. This report contains excerpts and commentary from the annual reports of the early biological survey. These excerpts represent one of the first rudimentary benefit-cost analyses 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 (excluding 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 the number of coyotes removed is likely determined by the number of lambs killed and 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 attached by Velcro to the throat of a sheep or goat.

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 in the range of $13,470,000 - $89,865,000 per annum.

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